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January 13, 2014

Mr. Kenneth Bardo - LU-9J VIA FEDEX
U.S. EPA Region V
Corrective Action Section
77 West Jackson Boulevard
Chicago, IL 60604-3507

Re: Long-Term Monitoring Program
2014 Periodic Technical Review (Evaluation of 3Q08 - 3Q13 Data) and Northern Plume Stability Analysis
Solutia Inc., W. G. Krummrich Plant, Sauget, IL

Dear Mr. Bardo:

On August 2, 2010, Solutia submitted a "Periodic Technical Review" evaluating the "Long-Term" groundwater monitoring data collected from 3rd quarter 2008 through 2nd quarter 2010, i.e., since the February 2008 Final Decision, and making recommendations for changes going forward.

Solutia has now completed evaluation of three more years of the subject data, i.e., through 3rd quarter 2013; see enclosure. As noted therein, Solutia recommends the following monitoring program changes:

- reduce groundwater monitoring frequency from quarterly to annually every February, the month with more repeatable, typical river levels than other months;

- eliminate monitoring for:

    - semivolatile organic compounds (specifically 4-chloroaniline, 2-chlorophenol, 1,4-dioxane, and 1,2,4-trichlorobenzene) in the five Benzene Storage Area (BSA) monitoring wells; and

    - ethane/ethene, nitrate, and sulfate in all monitoring wells; and

- discontinue phospholipid fatty acids (PLFA) analyses and compound-specific isotope analyses (stable isotope probing [SIP]).

In addition to the long-term monitoring conducted since 3rd quarter 2008, Solutia has conducted "supplemental" monitoring since 3rd quarter 2011, at U.S. EPA's request, for benzene and chlorobenzenes in Deep Hydrogeologic Unit (DHU) groundwater in the area north of the W. G. Krummrich Plant. A review of the resulting data is presented in "Northern Plume Stability Analysis," included as Attachment 3 to the enclosed 2014 Periodic Technical Review. The northern plume has been determined to be stable based on data from wells GWE-3D and 5D and ESL-MW-A, C1, and D1 and over a very broad range of Mississippi River levels. Nevertheless, consistent with a 2011 GSI Environmental study of variability in groundwater monitoring data sets, Solutia proposes to sample the above wells two more times, in February 2014 and February 2015, after which we anticipate that U.S. EPA can re-assign the "yes" determinations it first made in 2004 for Corrective Action Environmental Indicators CA725 - "Current Human Exposures Under Control" and CA750 – "Migration of Contaminated Groundwater Under Control."

Finally, reiterating from our 2010 submittal, Solutia proposes to discontinue semiannual sampling of surface water and sediment from the Mississippi River for volatile and semivolatile organic compounds. As demonstrated by the attached tables of such data collected from 3rd quarter 2008 through 3rd quarter 2013, there were only two detections (72 and 9.8 ug/kg chlorobenzene in sediment at sampling location R-3 during 3rd quarter 2009 and 1st quarter 2012, respectively) out of 270 possibilities (2 media x 3 sample locations x 9 analytes x 5 sampling events). Furthermore, there were only four additional estimated (J) detections in sediment and two in surface water.

I'd appreciate your prompt response because the 1st quarter 2014 sampling is scheduled to take place in February. If necessary to facilitate that response, Dr. Chuck Newell of GSI Environmental and I can discuss this submittal in a conference call or meeting with U.S. EPA and USGS.

If you have any questions or comments regarding this report, please contact me at (314) 674-3312 or gmrina@eastman.com

Sincerely,

Gerald M. Rinaldi
Manager, Remediation Services

Attachment and Enclosure

cc: Distribution List

DISTRIBUTION LIST

Periodic Technical Review of Long-Term Monitoring Program and Northern Plume Stability Analysis
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Results of Long-Term Monitoring of SURFACE WATER

ID	Media	Units	Chemical Group	Chemical	3rd Quarter 2008 Result	1st Quarter 2009 Result	3rd Quarter 2009 Result	1st Quarter 2010 Result	1st Quarter 2012 Result
R-1	Surface Water	µg/kg	VOCs	Benzene	< 1	< 1	< 1	< 1	< 1
	Surface Water	µg/kg	VOCs	Chlorobenzene	< 1	< 1	< 1	< 1	< 1
	Surface Water	µg/kg	VOCs	1,2-Dichlorobenzene	< 1	< 1	< 1	< 1	< 1
	Surface Water	µg/kg	VOCs	1,3-Dichlorobenzene	< 1	< 1	< 1	< 1	< 1
	Surface Water	µg/kg	VOCs	1,4-Dichlorobenzene	< 1	< 1	< 1	< 1	< 1
	Surface Water	µg/kg	SVOCs	P-Chloroaniline	< 19	< 19	< 19	< 19	< 19
	Surface Water	µg/kg	SVOCs	2-Chlorophenol	< 9.7	< 9.7	< 9.5	< 9.4	< 9.5
	Surface Water	µg/kg	SVOCs	1,4-Dioxane	< 9.7	< 9.7	< 9.5	< 9.4	< 9.5
	Surface Water	µg/kg	SVOCs		< 9.7	< 9.7	< 9.5	< 9.4	< 9.5
R-2	Surface Water	µg/kg	VOCs	Benzene	< 1	< 1	< 1	< 1	< 1
	Surface Water	µg/kg	VOCs	Chlorobenzene	< 1	< 1	< 1	< 1	< 1
	Surface Water	µg/kg	VOCs	1,2-Dichlorobenzene	< 1	< 1	< 1	< 1	< 1
	Surface Water	µg/kg	VOCs	1,3-Dichlorobenzene	< 1	< 1	< 1	< 1	< 1
	Surface Water	µg/kg	VOCs	1,4-Dichlorobenzene	< 1	< 1	< 1	**0.35 J**	< 1
	Surface Water	µg/kg	SVOCs	P-Chloroaniline	< 19	< 19	< 19	< 19	< 19
	Surface Water	µg/kg	SVOCs	2-Chlorophenol	< 9.7	< 9.7	< 9.5	< 9.4	< 9.6
	Surface Water	µg/kg	SVOCs	1,4-Dioxane	< 9.7	< 9.7	< 9.5	< 9.4	< 9.6
	Surface Water	µg/kg	SVOCs	1,2,4-Trichlorobenzene	< 9.7	< 9.7	< 9.5	< 9.4	< 9.6
R-3	Surface Water	µg/kg	VOCs	Benzene	< 1	< 1	< 1	< 1	< 1
	Surface Water	µg/kg	VOCs	Chlorobenzene	< 1	< 1	< 1	< 1	< 1
	Surface Water	µg/kg	VOCs	1,2-Dichlorobenzene	< 1	< 1	< 1	< 1	< 1
	Surface Water	µg/kg	VOCs	1,3-Dichlorobenzene	< 1	< 1	< 1	< 1	< 1
	Surface Water	µg/kg	VOCs	1,4-Dichlorobenzene	< 1	< 1	< 1	**0.37 J**	< 1
	Surface Water	µg/kg	SVOCs	P-Chloroaniline	< 19	< 19	< 19	< 19	< 19
	Surface Water	µg/kg	SVOCs	2-Chlorophenol	< 9.7	< 9.7	< 9.5	< 9.4	< 9.5
	Surface Water	µg/kg	SVOCs	1,4-Dioxane	< 9.7	< 9.7	< 9.5	< 9.4	< 9.5
	Surface Water	µg/kg	SVOCs	1,2,4-Trichlorobenzene	< 9.7	< 9.7	< 9.5	< 9.4	< 9.5

Notes:
µg/L = micrograms per liter
< = Result is non-detect, less than the reporting limit given.
J = Estimated value
Bold indicates concentration greater than laboratory reporting limit

Results of Long-Term Monitoring of SEDIMENT

ID	Media	Units	Chemical Group	Chemical	3rd Quarter 2008 Result	1st Quarter 2009 Result	3rd Quarter 2009 Result	1st Quarter 2010 Result	1st Quarter 2012 Result
R-1	Sediment	µg/kg	VOCs	Benzene	< 4.6	< 13	< 5.3 J	< 4.7	< 7
	Sediment	µg/kg	VOCs	Chlorobenzene	< 4.6	< 13	< 5.3 J	< 4.7	< 7
	Sediment	µg/kg	VOCs	1,2-Dichlorobenzene	< 4.6	< 13	< 5.3 J	< 4.7	< 7
	Sediment	µg/kg	VOCs	1,3-Dichlorobenzene	< 4.6	< 13	< 5.3 J	< 4.7	< 7
	Sediment	µg/kg	VOCs	1,4-Dichlorobenzene	< 4.6	< 13	< 5.3 J	< 4.7	< 7
	Sediment	µg/kg	SVOCs	P-Chloroaniline	< 840	< 930	< 840	< 810	< 830
	Sediment	µg/kg	SVOCs	2-Chlorophenol	< 420	< 470	< 420	< 410	< 410
	Sediment	µg/kg	SVOCs	1,4-Dioxane	< 420	< 470	< 420 J	< 410	< 410
	Sediment	µg/kg	SVOCs	1,2,4-Trichlorobenzene	< 420	< 470	< 420	< 410	< 410
R-2	Sediment	µg/kg	VOCs	Benzene	< 4.9	< 4.8	< 4.9	< 5	< 4.6
	Sediment	µg/kg	VOCs	Chlorobenzene	< 4.9	< 4.8	< 4.9	< 5	< 4.6
	Sediment	µg/kg	VOCs	1,2-Dichlorobenzene	< 4.9	< 4.8	< 4.9	< 5	< 4.6
	Sediment	µg/kg	VOCs	1,3-Dichlorobenzene	< 4.9	< 4.8	< 4.9	< 5	< 4.6
	Sediment	µg/kg	VOCs	1,4-Dichlorobenzene	< 4.9	< 4.8	< 4.9	< 5	< 4.6
	Sediment	µg/kg	SVOCs	P-Chloroaniline	< 800	< 790	< 810	< 780	< 780
	Sediment	µg/kg	SVOCs	2-Chlorophenol	< 400	< 390	< 400	< 390	< 390
	Sediment	µg/kg	SVOCs	1,4-Dioxane	< 400	< 390	< 400	< 390	< 390
	Sediment	µg/kg	SVOCs	1,2,4-Trichlorobenzene	< 400	< 390	< 400	< 390	< 390
R-3	Sediment	µg/kg	VOCs	Benzene	< 4.8	< 4	**3.5 J**	< 5	< 4.3
	Sediment	µg/kg	VOCs	Chlorobenzene	**4.4 J**	**2.9 J**	**72**	< 5	**9.8**
	Sediment	µg/kg	VOCs	1,2-Dichlorobenzene	< 4.8	< 4	< 4.7	< 5	< 4.3
	Sediment	µg/kg	VOCs	1,3-Dichlorobenzene	< 4.8	< 4	< 4.7	< 5	< 4.3
	Sediment	µg/kg	VOCs	1,4-Dichlorobenzene	< 4.8	< 4	**1.6 J**	< 5	< 4.3
	Sediment	µg/kg	SVOCs	P-Chloroaniline	< 680	< 810	< 730	< 770	< 770
	Sediment	µg/kg	SVOCs	2-Chlorophenol	< 340	< 400	< 360	< 390	< 390
	Sediment	µg/kg	SVOCs	1,4-Dioxane	< 340	< 400	< 360 J	< 390	< 390
	Sediment	µg/kg	SVOCs	1,2,4-Trichlorobenzene	< 340	< 400	< 360	< 390	< 390

Notes:
µg/kg = micrograms per kilogram
< = Result is non-detect, less than the reporting limit given
J = Estimated value
Bold indicates concentration greater than laboratory reporting limit

929262

2014 PERIODIC TECHNICAL REVIEW OF LONG-TERM MONITORING PROGRAM

SOLUTIA INC.
W.G. KRUMMRICH FACILITY
SAUGET, ILLINOIS

January 2014

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2014 PERIODIC TECHNICAL REVIEW
OF LONG-TERM MONITORING PROGRAM
SOLUTIA INC.
W.G. KRUMMRICH FACILITY
SAUGET, ILLINOIS

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ATTACHMENTS

Attachment 1 Constituent Trend Analysis – The Mann Kendall Test
Attachment 2 Truex et al., 2006: Geochemical Conditions (Select Pages)
Attachment 3 Northern Plume Stability Analysis

2014 PERIODIC TECHNICAL REVIEW OF LONG-TERM MONITORING PROGRAM

SOLUTIA INC., W.G. KRUMMRICH FACILITY
SAUGET, ILLINOIS

1.0 EXECUTIVE SUMMARY

Conclusions

- Overall, the W.G. Krummrich Facility benzene and chlorobenzene groundwater plumes have been decreasing and stable in concentration, respectively, since 2006.

- While there has been some change in the benzene and chlorobenzene plumes over time, the portions of the plumes near the Mississippi River have not changed substantially between 2006 and 2013, so there remains no unacceptable risk to potential receptors.

- Significant mass is being destroyed by natural attenuation processes. No alternative technologies are needed to augment these natural attenuation processes.

- The plumes are geochemically either anoxic or anaerobic, which is supportive of anaerobic biodegradation processes for both benzene and chlorobenzene. Almost all wells show the presence of methane, an indirect indicator of benzene and chlorobenzene anaerobic biodegradation. Microbial analyses (phospholipid fatty acids (PLFA) and PLFA-stable isotope probing (PLFA-SIP)) show that naturally occurring biodegradation of benzene and chlorobenzene occurs readily in the subsurface under anaerobic conditions.

Recommendations

- Eliminate PLFA and PLFA-SIP, ethane/ethene, semi-volatile constituents in Benzene Storage Area (BSA) wells, nitrate, and sulfate from future monitoring.

- Change to annual monitoring, with the sampling program conducted in February, the month with more repeatable, typical river levels than other months.

- The overall assessment of current groundwater conditions indicates the plumes pose no unacceptable risk to potential receptors, and therefore supports revisions of the April 24, 2011, Corrective Action Environmental Indicator determinations to once again, as in the May 26, 2004 determinations, indicate that “current human exposures are under control” (CA725) and “migration of contaminated groundwater is under control” (CA750). However, Solutia proposes that U.S. Environmental Protection Agency (USEPA) defer revision of these Environmental Indicator determinations until the northern plume stability data collection program is completed in February 2015 (see Attachment 3). Those data are needed to confirm that the northern plume is adequately characterized and under control in addition to posing no unacceptable risk to potential receptors.

2.0 INTRODUCTION

The U.S. Environmental Protection Agency (USEPA) issued a Final Decision on February 26, 2008, regarding remediation of impacted groundwater originating from Solutia Inc. (Solutia)'s W. G. Krummrich Facility located in Sauget, Illinois, and hereafter referred to as the "Site." The Final Decision called for a plan to evaluate the effectiveness of Monitored Natural Attenuation (MNA) in controlling two groundwater plumes emanating from beneath the Site, one originating from a former Benzene Storage Area (BSA) that contains dissolved benzene (referred to as the BSA Plume) and one originating from a former Chlorobenzene Process Area (CPA) that contains dissolved chlorobenzenes (referred to as the CPA Plume). Downgradient of the source areas, the plumes appear to be co-mingled. Figure 1 shows the Site, the area of interest extending from the Site westward (i.e., hydraulically downgradient) to the Mississippi River, the locations of the BSA and CPA, and the monitoring wells used to characterize the BSA and CPA Plumes. Figure 1 also shows supplemental monitoring wells and Illinois Department of Transportation (IDOT) wells north of the Site. This submittal satisfies the Final Decision's requirement that Solutia "conduct periodic technical reviews of data from the long-term monitoring program to evaluate site conditions … [and] submit the periodic technical review as an assessment report to USEPA for review and comment every three years"; the first such review was submitted in August 2010 (Solutia, 2010).

A Long-Term Monitoring Program (LTMP) work plan was developed to generate data that could be used to assess whether the plumes are naturally attenuating (Solutia, 2009). The activities implemented under the work plan include collecting quarterly groundwater samples from the monitoring wells shown on Figure 1. Five of the wells are located along the alignment of the BSA Plume (i.e., BSA-MW-1S, BSA-MW-2D, BSA-MW-3D, BSA-MW-4D, and BSA-MW-5D). The remaining five wells are located along the alignment of the CPA Plume (i.e., CPA-MW-1D through CPA-MW-5D).

The wells are sampled using low-flow sampling techniques. Indicator parameters monitored during purging of the wells using a flow cell include pH, specific conductance, redox potential, and dissolved oxygen. Groundwater samples collected during the sampling events are currently analyzed for the following parameters: benzene, monochlorobenzene (CB), dichlorobenzene (DCB) isomers (1,2-DCB; 1,3-DCB; and 1,4-DCB), total and dissolved organic carbon, total and dissolved iron and manganese, nitrate, sulfate, dissolved gases (i.e., carbon dioxide, ethane, ethylene, and methane), chloride, and alkalinity. Selected samples are also analyzed for 2-chlorophenol (all LTM wells), 1,2,4-trichlorobenzene (all LTM wells), 4-chloroaniline (wells CPA-MW-3D, CPA-MW-4D, and CPA-MW-5D), and 1,4-dioxane (wells BSA-MW-2D, BSA-MW-3D, BSA-MW-4D, and BSA-MW-5D) on a semi-annual basis. In addition to these parameters, samples collected from wells BSA-MW-2D and CPA-MW-3D are analyzed by a combination of phospholipid fatty acid (PLFA) and PLFA-stable isotope probing (PLFA-SIP) on a quarterly basis, which can provide direct evidence of biodegradation of a particular constituent of interest.[1]

In accordance with the LTMP work plan, MNA of the BSA and CPA plumes is evaluated based on the following:

1. Demonstration of a clear and meaningful trend of decreasing contaminant mass or concentration;
2. Indirect demonstration of the types of natural attenuation processes active at the Site; and
3. Direct evidence of the occurrence of biodegradation processes at the Site.

Attachment 1 presents a Mann-Kendall trend analysis of the analytical data. Attachment 2 describes a method to determine if the geochemical environment of a groundwater plume is aerobic, anaerobic, or anoxic (Truex et al., 2006). Attachment 3, Northern Plume Stability Analysis, provides an MNA assessment of constituents detected in some of the supplemental monitoring wells north of the Site.

3.0 RELEVANT BACKGROUND INFORMATION

A number of investigations have been performed to characterize the Site and the groundwater plumes downgradient from the Site. In particular, these investigations obtained data used to determine the aquifer characteristics and existing hydrogeologic conditions, and to assess the extent of the BSA and CPA plumes. Relevant hydrogeologic information pertaining to the area located north of the Site is included in Attachment 3, Northern Plume Stability Analysis. The existing hydrogeologic information relevant to the evaluation of MNA is discussed in the following sections.

3.1 Aquifer Characteristics

Based on the description from the RCRA Corrective Measures Study for the Krummrich Plant (Solutia, 2004), the depth to bedrock is approximately 110 feet below the ground surface (bgs), and approximately 140 feet below the crest of 30-foot high levees along the banks of the Mississippi River.

Three distinct hydrologic units have been identified in the unconsolidated soil which, downward from the ground surface, are the

- Shallow Hydrogeologic Unit (SHU),

[1] PLFA-SIP is performed by deploying a Bio-Trap® in a well that is screened within the plume. The trap is baited with the constituents of interest (in this case benzene and CB) that have been labeled with 13-carbon (^{13}C). After a period of time, the trap is retrieved and the biomass that accumulates on the trap analyzed for ^{13}C. If the biomass is enriched with ^{13}C, it can be concluded with certainty that microorganisms within the aquifer around the well are biodegrading the constituent of interest.

- Middle Hydrogeologic Unit (MHU), and
- Deep Hydrogeologic Unit (DHU).

The SHU is approximately 30 feet thick and the MHU and DHU are each approximately 40 feet thick. The boundaries between the three units are gradational. The SHU consists of low-permeability floodplain deposits including clay, silt, and sand. The MHU and DHU consist of high-permeability glacial outwash deposits that coarsen downward. The MHU and DHU consist primarily of medium to coarse sand. The DHU includes gravel, cobbles, and boulders near its base.

The MHU and DHU are the primary migration pathways for constituents present in groundwater (Solutia, 2005, 2009). The farthest downgradient extent of migration and the largest area of impacted groundwater occurs within the DHU. Accordingly, with the exception of SHU well BSA-MW-1S in the BSA source area, the wells monitored for MNA parameters are screened in the DHU. Based upon the gradational boundary between the MHU and DHU and the similarities in grain-size and permeability, the aquifer properties of the MHU and DHU are assumed to be similar for the evaluation of MNA. The aquifer properties summarized in Exhibit 1 were used to develop the physical/chemical data in Section 4.2.1.

Exhibit 1: Typical Aquifer Properties for the MHU/DHU Units

Soil Property	Value Used in MNA Evaluation Analyses
Hydraulic Conductivity (K)	0.14 centimeters per second (cm/sec) (GSI, 2008)
Hydraulic Gradient (i)	0.0014 feet/foot (BSA Plume) 0.0013 feet/foot (CPA Plume)
Bulk Density (ρ_b, dry unit weight)	118.3 pounds per cubic foot (URS, 2008) (1,895 kilograms per cubic meter)
Porosity (n)	28.8% (URS, 2008)
Effective Porosity (n_e)	20% (Env. Tech., 1997)
Fraction Organic Carbon (f_{oc})	0.0016 (Solutia, 2004)

3.2 Site Hydrogeology

Hydrogeologic conditions are also an important consideration when evaluating MNA. Site data were reviewed to develop an understanding of the hydrogeologic conditions that could influence the interpretation of the occurrence and extent of MNA. Relevant hydrogeologic conditions at the Site are briefly discussed below. A map of the Site showing source areas and generalized directions of groundwater flow is included as Figure 1. A representative hydrogeologic cross section with arrows showing the general pattern of groundwater flow and the general division between the three primary hydrogeologic units (SHU, MHU, and DHU) is depicted in Figure 2.

The Mississippi River is an important hydrologic feature that affects groundwater flow in the vicinity of the Site. Since Spring 2006[2], the river stage near the Site has varied over 45 feet, from an approximate elevation of 375 feet Mean Sea Level (MSL) in January 2013 to 421 feet MSL in June 2013 (NAVD 88). The frequency of different river stage levels based on historical data is shown in Table 1.

During periods of low river stage (i.e., generally below elevation 390 feet MSL), groundwater would normally discharge to the river. However, much of the groundwater in the plume is intercepted and recovered before it can discharge to the river. The interception and recovery of groundwater in the plume is achieved by operation of the Groundwater Migration Control System (GMCS) at Sauget Superfund Site R, which is located southwest of the Site adjacent to the river (Figure 1).

During periods of high river stage, the river elevation is higher than groundwater levels in the MHU and/or DHU, and the river is a source of recharge to these units. As such, the Mississippi River may provide a source for electron acceptors (e.g., nitrate) during periods of recharge. In addition, higher groundwater levels (during recharge) may mobilize sulfate from the vadose zone into groundwater. Sulfate may serve as an electron acceptor during biodegradation of COI.

The transport of constituents of interest (COI) is also affected by groundwater hydraulic gradients, which have horizontal and vertical components. The horizontal hydraulic gradient is toward the river during periods of low river stage, and away from the river during periods of high river stage, with an intermittent northerly flow component under certain conditions (see Attachment 3 for details). The vertical hydraulic gradient is typically downward in the vicinity of the Site and diminishes to zero (i.e., near-horizontal flow) between the Site and the river. The vertical gradient near the river is upwards when the river stage is low and groundwater is discharging to the river and downwards when the river stage is high and groundwater is recharged by the river.

Another consideration that affects the transport of COI from the CPA and BSA is the groundwater interception system referred to as the GMCS. The GMCS, located along the riverfront at the Sauget Superfund Site R, consists of a u-shaped barrier wall and three groundwater extraction wells (Figure 1). The barrier wall is keyed into the underlying bedrock, and the extraction wells have a total pumping capacity of approximately 2,200 gallons per minute (gpm). The eastern side of the barrier wall is open so as to capture groundwater flowing towards the river. The GMCS uses an Automated Data Acquisition System (ADAS) to calculate the pumping rate required to avoid groundwater flow around the barrier wall. The pumping rate depends largely on the hydraulic head differential between the groundwater and the adjacent Mississippi River. When the river level is falling rapidly, the horizontal hydraulic gradient is steeper and higher pumping rates are needed to capture the groundwater. When the groundwater and river levels are close to one another, the pumping rates are minimal. During

[2] The first quarterly event for the Plume Stability Monitoring Program occurred in March 2006.

periods of high river stage and bank recharge, the pumps are turned off because groundwater flows eastward, away from the river.

KEY POINTS: Site Hydrogeology
• Most of plume migration is in MHU/DHU units. • The Mississippi River elevation is an important control of groundwater flow; during some high river level periods, flow is from the river to the aquifer. There is also a northerly flow component associated with high-river-level events (see Attachment 3). • Groundwater flow is also affected by the GMCS.

4.0 INTERPRETATION

4.1 Extent of BSA and CPA Plumes

Both the benzene and chlorobenzene plumes extend from source areas at the W.G. Krummrich Facility to much-lower-concentration areas near the Mississippi River. Figure 3 shows the benzene plume in 2006 and 2013, and Figure 4 shows the chlorobenzene plume in 2006 and 2013. While both the benzene and chlorobenzene plumes have some differences between 2006 and 2013, in general, the extent (footprint) of both plumes is relatively stable with near-river concentrations that are two to four orders of magnitude lower than source area concentrations (see Section 4.3.1).

There is an intermittent northerly groundwater flow component that does produce some northerly migration of chlorobenzene and, to a lesser extent, benzene. The stability of the Northern Plume is evaluated in Attachment 3.

4.2 Overview of Natural Attenuation Processes

4.2.1 Physical and Chemical

Advection refers to the transport of solutes by the bulk movement of groundwater. Advection is the most important process driving the downgradient migration of aqueous-phase constituents in groundwater. The rate at which advective transport influences dissolved-phase constituent migration is referred to as the seepage velocity. Seepage velocity is a key parameter in natural attenuation studies because it can be used to estimate constituent travel time.

Based on the regional groundwater fate and transport model (GSI, 2008; GSI, 2012), estimated seepage velocities for groundwater for the areas of the BSA and CPA plumes range from approximately 570 to 900 feet per year (ft/yr) in the MHU and 700 to 800 ft/yr in the DHU.

Hydrodynamic dispersion is the process whereby a groundwater plume mixes with clean water as the plume migrates through a porous media. This mixing occurs as a result of two processes: mechanical dispersion due to the change in groundwater flow paths as groundwater migrates through a porous media, and molecular diffusion of contaminants from high-concentration to low-concentration zones. In general, dispersion is a second-order process that is typically not a significant contributor to natural attenuation (e.g., Hadley and Newell, 2013). At the Site, there may be more mixing of the groundwater plume with clean groundwater due to the intermittent northerly flow component (see Attachment 3).

Sorption is a non-destructive process in which organic compounds are sorbed to the matrix of the water-bearing unit and is represented by a retardation factor (Wiedemeier et al., 1999). The retardation factor indicates two processes: 1) the degree to which a particular constituent moves slower than groundwater seepage velocity, and 2) the ratio of total constituent mass per volume of aquifer matrix to the volume of dissolved constituents. As shown below, sorption of the key Site constituents was evaluated from distribution coefficients calculated using octanol-water partition coefficients (K_{oc}) taken from the Illinois Environmental Protection Agency's Tiered Approach to Corrective Action Objectives (TACO) standard (35 IAC 742) and assuming a fraction organic carbon (f_{oc}) of 0.0016 (Solutia, 2004):

Constituent	Soil-Water Distribution Coefficient, K_d (L/kg)	Retardation Factor, R (unitless)
Benzene	9.4×10^{-2}	1.5
Chlorobenzene	3.5×10^{-1}	3.0

A retardation factor of 3.0 for chlorobenzene indicates the chemical velocity of the chlorobenzene plume is three times slower than the typical groundwater seepage velocity at a site, and for every gram of chlorobenzene in the aqueous phase, two grams of chlorobenzene are sorbed to naturally occurring organic carbon on the aquifer material (sand and gravel) in the MHU and DHU.

KEY POINTS: Advection, Dispersion, and Sorption Processes

- Average groundwater seepage velocities range from 570 to 900 feet per year in the MHU/DHU.
- Dispersion is likely to be a less important attenuation mechanism compared to other attenuation processes.
- Both benzene and chlorobenzene will sorb to the aquifer material with estimated retardation factors of 1.5 and 3.0, respectively. This is not likely to be a strong attenuation mechanism.

4.2.2 Biodegradation

Biodegradation is a microbial-mediated destructive attenuation process. Pathways and rates are a function of the compound being transformed and the geochemical conditions within the hydrogeologic unit. Aerobic reactions occur in the presence of oxygen, while anaerobic reactions occur when oxygen has been depleted. Geochemical conditions for the W.G. Krummrich Facility plume and biodegradation-related data are presented in Section 4.4 and Figure 7.

Benzene can be rapidly mineralized to CO_2 in aerobic conditions by a number of different types of indigenous microbes (Alvarez and Vogel, 1991; Borden et al., 1994). It is generally accepted that this type of microbial metabolic capacity is widespread in nature. Benzene is also biodegradable in anaerobic environments (Bolt et al., 2002; Lovley, 2000; Johnson et al., 2003; Foght, 2008), such as iron-reducing (Anderson et al., 1998), sulfate-reducing (Lovley et al., 1995), nitrate-reducing (Burland and Edwards, 1999), and methanogenic conditions (Weiner and Lovley, 1998). In general, reaction rates for anaerobic degradation are lower than those observed for aerobic biodegradation.

Chlorobenzene can be degraded in both aerobic and anaerobic geochemical environments. Several studies have shown that aerobic microorganisms utilize chlorobenzenes (Reineke and Knackmuss, 1988; van der Meer et al., 1998; Rittman and McCarty, 2001; Elango, 2010) as growth-promoting substrates. These and other studies have further indicated the microorganisms capable of carrying out such degradation reactions are commonly encountered at contaminated sites (Dominguez et al., 2008). Chlorobenzene is an anaerobic degradation product of the dichlorobenzenes.

Several reports have documented the anaerobic biodegradation of chlorobenzenes (e.g., Liang, et al. 2013; Sims et al., 1991; Middeldorp et al., 1997; Heidrich et al., 2004; Kaschl et al., 2005; Fung et al., 2009). The reductive dechlorination pathway for dichlorobenzenes proceeds via the sequential removal of a chlorine atom from the molecule. Further reduction of chlorobenzene to benzene under methanogenic conditions has been shown by field and laboratory observations (Nowak et al., 1996; Kaschl et al., 2005; Fung et al., 2009), and identification of at least one microorganism that can carry out this reaction has been documented (Liang et al., 2013; Nelson et al., 2011). Direct anaerobic pathways of chlorobenzene to CO_2 (mineralization) has been reported by Nijenhuis et al. (2007) and Kaschl et al. (2005).

KEY POINTS: Biodegradation Processes

- Both benzene and chlorobenzene can be degraded by naturally occurring aerobic bacteria in groundwater.
- Both benzene and chlorobenzene can be degraded by naturally occurring anaerobic bacteria in groundwater. This has been demonstrated both in lab studies and at field research sites using isotopes and other lines of evidence.
- When chlorobenzene is degraded anaerobically via reductive dechlorination, benzene is produced.

4.3 Concentration Trends Analysis

4.3.1 Spatial Concentration Trends

The overall downgradient extent of the benzene plume (as defined by the 100-microgram-per-liter (ug/L) contour) in 2013 was similar to the downgradient extent in 2006 (Figure 3 and Table 2). Benzene concentrations in wells CPA-MW-4D and BSA-MW-3D and the near-river wells have similar or lower concentrations in 2013 compared to 2006.

The overall extent of the chlorobenzene plume is very similar in 2013 compared to 2006 (Figure 4 and Table 2) and therefore stable also.

4.3.2 Temporal Concentration Trends

A statistical analysis of groundwater temporal trends, from 2006 to 2013, in individual wells using a Mann-Kendall analysis was performed for the W.G. Krummrich Facility plumes and shows stable or decreasing concentrations in most monitoring wells (Attachment 1).

For benzene, only two of eight wells that could be statistically analyzed had increasing concentration trends, one of them in the CPA and another immediately downgradient of the BSA source area (Figure 5 and Attachment 1). BSA-MW-2D was classified as having an *increasing* trend over the seven-year period, with an increase in concentration from 2006 to late 2010, followed by stable concentrations over the past three years. Well CPA-MW-3D has shown a higher-lower-higher concentration pattern since 2006, but overall concentrations are statistically *stable*. More importantly, the average (geometric mean or geomean) of the near-river benzene concentrations (wells BSA-MW-4D and 5D and CPA-MW-4D and 5D) over the seven-year period is 34 micrograms per liter (ug/L), compared to 146,000 ug/L for the two source area wells (BSA-MW-1S and CPA-MW-1D), demonstrating very active attenuation processes have consistently degraded the benzene plume. The three closest wells to the river with enough detectable benzene concentrations to evaluate statistical trends (BSA-MW-3D, BSA-MW-4D, CPA-MW-4D) exhibited *stable*, *decreasing*, and *decreasing* trends, respectively. The average (geomean) of all ten wells since 2nd Quarter 2006 has shown a *decreasing* trend.

For chlorobenzene, three wells had increasing, three stable, and two decreasing concentration trends since 2006 (Figure 6 and Attachment 1). While well BSA-MW-3D has shown a statistical *increase* over time, the well side-gradient (CPA-MW-4D) to the north has shown a statistical *decrease*, suggesting the core of the plume shifts slightly from north to south (left to right on Figure 6). Significant attenuation has been observed since 2006, with an average (geomean) concentration from two source area wells (CPA-MW-1D and 2D) of 21,100 ug/L and the average (geomean) of the three near-river wells (BSA-MW-4D and 5D and CPA-MW-4D and 5D) of 811 ug/L. When analyzed using the Mann-Kendall method, the three near-river wells all show a statistical *stable* trend (Figure 6 and Attachment 1). The average (geomean) of all ten wells since 2nd Quarter 2006 has shown a *stable* trend. Some wells show the effect of clean river water entering the aquifer during periods of high river level when chlorobenzene concentrations approach very low levels (e.g., BSA-MW-5D, Attachment 1, Page 3).

KEY POINTS: Plume Spatial and Temporal Trends
• Overall, the benzene plume has been *decreasing* in concentration since 2006 and the chlorobenzene plume has been *stable*.
• Significant attenuation is observed between the source area and near-river wells for both the benzene and chlorobenzene plumes.

4.4 Biodegradation Analysis

4.4.1 Indirect Indicators: Geochemical Conditions

An analysis of the geochemical data (Table 3 and Figure 7) shows most of the monitoring wells exhibit low-dissolved oxygen, low-ORP, and high methane conditions. In general, wells with high benzene and chlorobenzene concentrations appear to show high methane concentrations, indicating methanogenic conditions are more prevalent when there is considerable oxygen demand in the form of benzene and chlorobenzene. Both benzene and chlorobenzene can be degraded by anaerobic bacteria under methanogenic conditions, and the presence of methane in groundwater is likely a byproduct of anaerobic degradation.

As shown on Figure 7, three wells showed a change in geochemical condition from 2006 to 2013, but these changes are likely due to natural variability in the monitoring data rather than any long-term trend. Similar to constituent data like benzene and chlorobenzene, parameters such as dissolved oxygen, sulfate, and methane (the key parameters for the geochemical categorization procedure) have variability related to heterogeneity, changing groundwater flow conditions, and other factors.

A groundwater plume's geochemical environmental can be defined using standard geochemical measurements (dissolved oxygen, nitrate, sulfate, ferrous iron, methane, total organic carbon, etc.) using a method presented by Truex et al. (2006) (reproduced in Attachment 2). With this method, the groundwater geochemistry can be defined as aerobic, anoxic, or anaerobic.

In general, aerobic conditions will support the highest degradation rates. Anaerobic and anoxic conditions will also support the biodegradation of both benzene and chlorobenzene, although anaerobic processes may be interrupted if there is a switch to sustained aerobic conditions that disrupts the anaerobic microbial consortium.

4.4.2 Direct Indicators: PLFA and PLFA-SIP Analysis

Phospholipid Fatty Acids (PLFA) and PLFA-Stable Isotope Probing (PLFA-SIP) analyses have been conducted at the Site to determine whether biodegradation of benzene and chlorobenzene is occurring under natural conditions. These analyses are discussed in detail below, with data presented in Table 4.

PLFA Analysis

Phospholipid fatty acids are a primary component of the membranes of all living cells and decay rapidly upon cell death. Therefore, the amount of PLFA present in a sample is a direct measure of the sample's viable biomass. In the field, data for PLFA analysis is collected using Bio-Traps®, a type of microcosm containing porous beads surrounded by a membrane. The Bio-Trap® is deployed within the screened interval of a monitoring well below the groundwater table. During the deployment, indigenous microorganisms present in the groundwater enter through the outside membrane of the trap and migrate into the porous beads. The microbes then attach to the beads and reproduce to form biofilms. Consequently, despite relatively low densities of microorganisms in the native groundwater, populations within the beads can be concentrated for PLFA analysis. However, for microorganisms to be detected, they must grow and reproduce within the bead. Therefore, only those microorganisms that are capable of survival and growth under the in situ conditions will be collected and detected by the analysis.

At the Site, PLFA analysis was conducted quarterly starting in the 3rd Quarter 2008 in all ten BSA and CPA wells. PLFA data are not specific to either benzene or chlorobenzene, and therefore data from all wells were averaged. No meaningful trends could be discerned in the PLFA biomass data, either with all the data averaged or by looking at individual wells (e.g., no increase in biomass was observed in well BSA-MW-2D in which benzene concentrations increased from 2006 to 2013; or in well CPA-MW-2D that went from aerobic conditions in 2006 to anaerobic in 2013). The PLFA dataset appears to be more of a general indicator that conditions are suitable for biodegradation, but does not seem to be able to follow or signal changes in the plume conditions over time.

Typically, PLFA analysis can help answer several key questions:

Are there sufficient bacteria to support biodegradation?

The potential for biodegradation to occur is often indicated by the overall abundance of viable microorganisms in a sample. Typically, populations are divided into low, moderate, and high:

- *Low* - indicative of viable populations between 10^3 and 10^4 cells/bead.
- *Moderate* - indicative of viable populations between 10^5 and 10^6 cells/bead.
- *High* - indicative of viable populations between 10^7 and 10^8 cells/bead.

At the wells that have been monitored, **moderate** levels of viable bacterial populations are indicated by the overall average of 1.6 x 10^5 cells/bead from all the Bio-Traps® installed in the ten wells over the 2008-2013 time period. There are considerable differences between wells and significant fluctuations over time for specific wells.

What are the main bacterial groups present in the aquifer, and what does that tell us about biodegradation at the site?

Biomarkers associated with *Proteobacteria* dominated the PLFA profiles Site-wide (64% of the biomass). These include the majority of hydrocarbon-metabolizing bacteria and are comprised of a wide variety of aerobes and anaerobes.

What is the health of bacterial population, and has it changed over time?

Slowed Growth and Decreased Permeability ratios from the PLFA analysis provide information on the "health" of the *Proteobacterial* community over time. Typically, long-term values of these ratios less than 0.25 are indicative of favorable environmental conditions for the bacteria (Microbial Insights, Inc.). At the Site, the average Slowed Growth of 0.27 ratio cy/cis and the average Decreased Permeability of 0.15 ratio trans/cis indicate slightly stressed/good environmental conditions for the bacteria. The long-term trends in the Slowed Growth and Decreased Permeability ratios do not show increasing stress to the bacteria over time (Figure 8).

PLFA-SIP Analysis

Microorganisms require a carbon source to grow and multiply. Biodegradation occurs when indigenous bacteria break down contaminants and the carbon in these contaminants is either used to grow microbial biomass or ends up as dissolved organic carbon.

If a microorganism feeds on a carbon source consisting entirely of ^{12}C (the most abundant stable form of carbon), then every carbon atom in the new cell growths will be ^{12}C. If however, the microorganism feeds on a carbon source enriched in ^{13}C, the other stable but rare (~1%) form of carbon, then the new cells will be significantly enriched in ^{13}C.

Stable Isotope Probing (SIP) can track if carbon in specific contaminants ends up as biomass or as dissolved organic carbon. In this method, a Bio-Trap® sampler is "baited" with specific contaminants containing ^{13}C, the distinct isotope of carbon. The Bio-Traps® are deployed for periods of ~30 days within the groundwater table at selected locations. During the deployment, indigenous bacteria enter the Bio-Trap®, feed on the synthesized compound, and grow and multiply. Upon completion of the deployment, the Bio-Traps® are recovered and analyzed.

The most frequently used form of SIP involves quantifying the incorporation of the stable isotope label into biomass using PLFA analysis, a technique known as PLFA-SIP.

At the Site, PLFA-SIP analysis was conducted quarterly starting in the 3rd Quarter 2008 at two wells: 1) well BSA-MW-2D using ^{13}C-labeled benzene, and 2) well CPA-MW-3D using ^{13}C-labeled chlorobenzene. Both of these wells were classified as having an "anaerobic" geochemical environment based on natural attenuation monitoring data. Results of the analysis are presented below.

Did the radiolabeled carbon in the contaminants end up in the biomass in the trap?

^{13}C enriched biomass is often reported as PLFA **del values** in units of per mil (‰ or parts per thousand) with this general correlation to biodegradation activity[3]:

- 0 and 100 ‰ : low level of biodegradation,
- 100 and 1,000 ‰ : moderate level of biodegradation,
- greater than 1,000 ‰ : high level of biodegradation.

The biomass analysis indicated a high level of biodegradation for benzene in the BSA well and low level of degradation in the well analyzed for chlorobenzene. The concentration of chlorobenzene in the chlorobenzene well was relatively low compared to the benzene well.

Constituent	Sampling Location	Concentration During Sampling Period (mg/L)	Avg. PLFA Del* (‰)	Result Interpretation
Benzene	BSA-MW-2D	16 - 290	2106	High degradation
Chlorobenzene	CPA-MW-3D	0.29 – 1.60	42	Low degradation

*Based on the arithmetic average of the 2008-2013 "Average PLFA Del" (as reported by the laboratory) temporal data.

What was the degradation rate of the contaminant in the baited Bio-Trap®?

Unless the ^{13}C labeled compound is degraded, little, if any, contaminant is lost from the baited Bio-Trap®. Consequently, observance of a reduction in concentrations from Bio-Trap pre-deployment levels provides an indirect measure of degradation in the aquifer.

At the Site, 18% and 23% losses in benzene and chlorobenzene concentrations, respectively, were observed on average during the Bio-Trap® deployment period (~30 days on average). When data from all the baited Bio-Traps® were considered, the average

[3] **ISOTOPE ENRICHMENT DATA: Del Values**

"^{13}C enrichment data is often reported as a del value. The del value is the difference between the isotopic ratio ($^{13}C/^{12}C$) of the sample (R_X) and a standard (R_{std}) normalized to the isotopic ratio of the standard (R_{std}) and multiplied by 1,000 (units are parts per thousand, denoted ‰).

R_{std} is the naturally occurring isotopic ratio and is approximately 0.011180 (roughly 1% of naturally occurring carbon is ^{13}C). The isotopic ratio, R_X, of PLFA is typically less than the R_{std} under natural conditions, resulting in a del value between -20 and -30‰. For a PLFA-SIP Bio-Trap® study, biodegradation and incorporation of the ^{13}C labeled compound into PLFA results in a larger $^{13}C/^{12}C$ ratio (R_X) and thus del values greater than under natural conditions. Because the del value is the difference between two ratios, values greater than 1000 ‰ are possible." (Microbial Insights, Inc.)

degradation half-lives were 84 days and 192 days for benzene and chlorobenzene, respectively.

Constituent	Sampling Location	Concentration During Sampling Period (mg/L)	Loss of ^{13}C Labeled Compound* (%)	Half Life* (days)
Benzene	BSA-MW-2D	16 - 290	18	84
Chlorobenzene	CPA-MW-3D	0.29 – 1.60	23	192

*Based on the arithmetic average of the 2008-2013 temporal data.

Did any radiolabeled carbon end up as dissolved organic carbon (carbon dioxide and other constituents of alkalinity)?

Under certain aerobic and anaerobic conditions, both benzene and chlorobenzene can be rapidly mineralized by a number of different types of indigenous microbes resulting in complete mineralization to CO_2 and water (Liang et al., 2013; Nijenhuis et al., 2007). The ^{13}C-enriched compounds degraded along this pathway cannot be seen in the biomass, but can be detected in the Dissolved Inorganic Carbon (DIC) molecules. Consequently, DIC results in an additional measure of the occurrence of degradation. Similar to PLFA, ^{13}C enriched DIC data is often reported as a del value.

The results indicated a high level of degradation for benzene in BSA-MW-2D and a moderate level of biodegradation for chlorobenzene in CPA-MW-3D.

Constituent	Sampling Location	Concentration During Sampling Period (mg/L)	DIC Del* (‰)	Result Interpretation
Benzene	BSA-MW-2D	16 - 290	4520	High degradation
Chlorobenzene	CPA-MW-3D	0.29 – 1.60	470	Moderate degradation

*Based on the arithmetic average of the 2008-2013 temporal data.

KEY POINTS: Molecular Biological Data

- Both the PLFA and PLFA-SIP data support the conclusion that both benzene and chlorobenzene can be biodegraded at the Site.
- The PLFA data indicate the primary bacteria that grew on the Bio-Trap® was a hydrocarbon-degrading bacteria. These bacteria are likely to be anaerobic as the groundwater in these wells has consistently been anaerobic over the last five years.
- The PLFA-SIP data indicated high degradation potential for benzene and low to moderate for chlorobenzene.

5.0 SUMMARY

Evaluation of the data from the groundwater monitoring conducted from 3rd Quarter 2008 through 3rd Quarter 2013 yielded the following conclusions:

Site Hydrogeology

- Most of plume migration is in MHU/DHU units.
- The Mississippi River elevation is an important control of groundwater flow; during some high river level periods, flow is from the river to the aquifer. There is also a northerly flow component associated with high river level events (see Attachment 3).
- Groundwater flow is also affected by the GMCS.

Advection, Dispersion, and Sorption Processes

- Average groundwater seepage velocities range from 570 to 900 ft/yr in the MHU/DHU.
- Dispersion is likely to be a less important attenuation mechanism compared to other attenuation processes.
- Both benzene and chlorobenzene will sorb to the aquifer material with estimated retardation factors of 1.5 and 3.0, respectively. This is not likely to be a strong attenuation mechanism.

Biodegradation Processes

- Both benzene and chlorobenzene can be degraded by naturally occurring aerobic bacteria in groundwater.
- Both benzene and chlorobenzene can be degraded by naturally occurring anaerobic bacteria in groundwater. This has been demonstrated both in laboratory studies and at field research sites using isotopes and other lines of evidence.
- When chlorobenzene is degraded anaerobically via reductive dechlorination, benzene is produced.

Plume Spatial and Temporal Trends

- Overall, the benzene plume has been decreasing in concentration since 2006, and the chlorobenzene plume has been stable.
- Significant attenuation is observed between the source area and near-river wells for both the benzene and chlorobenzene plumes.

Molecular Biological Data

- Both the PLFA and PLFA-SIP data support the conclusion that both benzene and chlorobenzene can be biodegraded at the Site.
- The PLFA data indicate the primary bacteria that grew on the Bio-Trap® was a hydrocarbon degrading bacteria. These bacteria are likely to be anaerobic as the groundwater in these wells has consistently been anaerobic over the last five years.
- The PLFA-SIP data indicated high degradation potential for benzene and low to moderate for chlorobenzene.

6.0 MONITORING PROGRAM RECOMMENDATIONS

The W.G. Krummrich Facility benzene and chlorobenzene plumes have been monitored quarterly for seven years. During the development of this Periodic Technical Review, the effectiveness of different data parameters and monitoring frequency were evaluated to develop recommendations about monitoring these plumes in the future. The following recommendations are discussed in detail in the sections below:

- Eliminate PLFA and PLFA-SIP, ethane/ethene, semi-volatile constituents in BSA wells, nitrate, and sulfate from future monitoring.
- Change to annual monitoring, with the sampling program conducted in February, the month with more repeatable, typical river levels than other months.
- This Periodic Technical Review can be used to support revisions of the April 24, 2011, Corrective Action Environmental Indicator determinations to once again, as in the May 26, 2004 determinations, indicate that “current human exposures are under control” (CA725) and “migration of contaminated groundwater is under control” (CA750).

6.1 Reduction in Monitoring Parameters

The historic groundwater monitoring program has provided insights about hydrogeology, spatial and temporal trends, and biodegradation processes in groundwater. For future monitoring, however, groundwater elevation, benzene, chlorobenzenes, dissolved oxygen, and methane can provide much of the key information being generated by the current monitoring program. In particular, future measurements of PLFA and PLFA-SIP, ethane/ethene, semi-volatile constituents (specifically 4-chloroaniline; 2-chlorophenol; 1,4-dioxane; and 1,2,4-trichlorobenzene in the five BSA monitoring wells), nitrate, and sulfate provide limited additional knowledge about plume stability, and analyses of these parameters are no longer needed.

6.2 Reduction in Monitoring Frequency

Stable or decreasing overall plume trends show:

1) no unacceptable risk to potential river receptors, and
2) direct and indirect evidence of biodegradation processes.

Therefore, a reduction in sampling frequency is recommended. One recent study of groundwater variability of three large groundwater datasets (McHugh et al., 2011) concluded that “[u]sing current monitoring methods, a monitoring frequency of more than one event per year serves primarily to characterize time-independent variability”, i.e., variability that does not contribute to understanding long-term trends. Sampling once per year at a time with relatively consistent river conditions (i.e., in February each year) will be sufficient to monitor plume stability in the future.

6.3 Corrective Action Environmental Indicators

The overall assessment of current groundwater conditions described in the sections above indicates the plumes pose no unacceptable risk to potential receptors, and therefore supports revisions of the April 24, 2011, Corrective Action Environmental Indicator determinations to once again, as in the May 26, 2004 determinations, indicate that “current human exposures are under control” (CA725) and “migration of contaminated groundwater is under control” (CA750). However, Solutia proposes that USEPA defer revision of these Environmental Indicator determinations until the northern plume stability data collection program is completed in February 2015 (see Attachment 3). Those data are needed to confirm that the northern plume is adequately characterized and under control in addition to posing no unacceptable risk to potential receptors.

7.0 LIST OF ACRONYMS

BSA	Benzene Storage Area
COI	Constituents of Interest
CPA	Chlorobenzene Process Area
DHU	Deep Hydrogeologic Unit
GMCS	Groundwater Migration Control System
MHU	Middle Hydrogeologic Unit
MNA	Monitored Natural Attenuation
MSL	Mean Sea Level
PLFA	Phospholipid Fatty Acid
SHU	Shallow Hydrogeologic Unit
SIP	Stable Isotope Probing

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2014 PERIODIC TECHNICAL REVIEW
OF LONG-TERM MONITORING PROGRAM

Solutia Inc.
W.G. Krummrich Facility
Sauget, Illinois

Tables

Table 1 Mississippi River at St. Louis Stage Duration Data
Table 2 Groundwater Concentrations 2006 through 2013
Table 3 Geochemical Parameters 2008 through 2013
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Table 1
Mississippi River at St. Louis
Stage Duration Data

River Stage (ft)	River Elevation (ft NAVD 88)	Percent Days Where This Stage Is Exceeded (Computed From 1861 to 2001) (%)	Percentage Days River Is At This Stage (%)	Number of Days River Is At This Stage Annually
50	429.6	0.00	0.00	0.00
49	428.6	0.00	0.00	0.01
48	427.6	0.01	0.01	0.02
47	426.6	0.01	0.01	0.02
46	425.6	0.04	0.02	0.08
45	424.6	0.04	0.01	0.02
44	423.6	0.05	0.00	0.01
43	422.6	0.06	0.01	0.04
42	421.6	0.07	0.01	0.05
41	420.6	0.08	0.01	0.05
40	419.6	0.01	0.00	0.00
39	418.6	0.16	0.15	0.57
38	417.6	0.25	0.08	0.30
37	416.6	0.3	0.05	0.19
36	415.6	0.4	0.10	0.37
35	414.6	0.6	0.20	0.73
34	413.6	0.8	0.20	0.73
33	412.6	1.1	0.30	1.10
32	411.6	1.3	0.20	0.73
31	410.6	1.7	0.40	1.46
30	409.6	2.3	0.60	2.19
29	408.6	2.9	0.60	2.19
28	407.6	3.7	0.80	2.92
27	406.6	4.5	0.80	2.92
26	405.6	5.5	1.00	3.65
25	404.6	6.9	1.40	5.11
24	403.6	8.4	1.50	5.48
23	402.6	10.0	1.60	5.84
22	401.6	11.6	1.60	5.84
21	400.6	13.5	1.90	6.94
20	399.6	15.7	2.20	8.04
19	398.6	18.0	2.30	8.40
18	397.6	20.0	2.00	7.31
17	396.6	23.6	3.60	13.15
16	395.6	26.8	3.20	11.69
15	394.6	30.1	3.30	12.05
14	393.6	33.8	3.70	13.51
13	392.6	37.6	3.80	13.88
12	391.6	41.4	3.80	13.88
11	390.6	45.6	4.20	15.34
10	389.6	50.4	4.80	17.53
9	388.6	55.3	4.90	17.90
8	387.6	60.4	5.10	18.63
7	386.6	65.6	5.20	18.99
6	385.6	71.0	5.40	19.72
5	384.6	76.0	5.00	18.26
4	383.6	80.9	4.90	17.90
3	382.6	85.4	4.50	16.44
2	381.6	89.1	3.70	13.51
1	380.6	92.2	3.10	11.32
0	379.6	95.0	2.80	10.23
-1	378.6	96.9	1.90	6.94
-2	377.6	98.1	1.20	4.38
-3	376.6	99.2	1.10	4.02
-4	375.6	99.7	0.50	1.83
-5	374.6	99.9	0.20	0.73
-6	373.6	100.0	0.10	0.37
-7	372.6	100.0	0.00	0.00

Notes:
1. River Stage and Percent Exceedance values obtained from Corps of Engineers table titled "Duration of Daily Observed Stage, Mississippi at St. Louis, Computed Over Years 1861 To 2002, Between Days 01 Jan and 31 Dec"
   Source: personal communication, A. Phillips, 2002.
2. River Stage was measured at USGS Gauge 07010000 located at River Mile 180 on the Eads Bridge. River Stage in ft NAVD 88 was obtained by adding 379.58 to the Stage in ft.

See last page of table for notes.

Table 2
Groundwater Concentrations - 2006 through 2013
Benzene and Chlorobenzene
BSA and CPA Wells

Quarter	BSA-MW-1S						BSA-MW-2D						BSA-MW-3D						BSA-MW-4D						BSA-MW-5D					
	Benzene			Chlorobenzene			Benzene			Chlorobenzene			Benzene			Chlorobenzene			Benzene			Chlorobenzene			Benzene			Chlorobenzene		
	Result (µg/L)	Lab Qual	URS Qual	Result (µg/L)	Lab Qual	URS Qual	Result (µg/L)	Lab Qual	URS Qual	Result (µg/L)	Lab Qual	URS Qual	Result (µg/L)	Lab Qual	URS Qual	Result (µg/L)	Lab Qual	URS Qual	Result (µg/L)	Lab Qual	URS Qual	Result (µg/L)	Lab Qual	URS Qual	Result (µg/L)	Lab Qual	URS Qual	Result (µg/L)	Lab Qual	URS Qual
1Q06	490,000			< 5,000			11,000			2,100			63			1,100	D													
2Q06	880,000			< 5,000			1,900	D	J	1,700	D	J	53			1,400			53			2,300	D		6,800		J	1,300		J
3Q06	570,000			< 5,000			11,000	D		2,300			56			1,200			51			2,100			6,200			1,200		
4Q06	630,000			< 5,000			5,500			1,700			100			980			38			1,600			4,600			600		
1Q07	91,000			770			4,000			2,000			90			1,000			32			1,300			4,100			490		
2Q07	1,100,000	D	J	< 5,000			1,400	D	J	1,100	D	J	44			1,100	D		4,500			2,800			3,500	D	J	330	D	J
3Q07	1,000,000	D		< 1,000			810			1,700			50			1,300			2,100	D		1,200	D		440	D		180		
4Q07	890,000	D		< 1,000			2,700	D		1,600	D		150			870			1,100			1,800			140			190		
1Q08	690,000			< 5,000			240			1,500			73			1,200	D		130			1,900			< 1			3.7		
2Q08	1,300,000	D		9,400			11,000			2,000			31			1,700			120			2,500			1.2			8.8		
3Q08	1,000,000	D		< 5,000			18,000			1,700			30			1,500			48			2,600	D		18			300	D	
4Q08	1,200,000			< 10,000			16,000			2,500			97			1,300			590		J	2,300		J	130			310		
1Q09	830,000			< 5,000			20,000			2,900			120			1,200			82			2,300			< 4			270		
2Q09	780,000			< 5,000			45,000	D		2,400			30			1,300			26			3,100			< 4			510		
3Q09	940,000			< 5,000			72,000	D		5,000			68			1,100			99			2,700	D		13			330		
4Q09	600,000			< 5,000			69,000			2,600			78			1,300			23			2,400			< 5			300		
1Q10	730,000			< 5,000			150,000			2,700			87			1,200			73			2,700			< 5			350		
2Q10	840,000			< 5,000			120,000			1,300			94			1,500			26			2,800			8.9			290		
3Q10	620,000			< 5,000			140,000			1,600			57			1,200			20			2,300			< 5			350		
4Q10	640,000			< 5,000			290,000	D		2,000			75			1,100			30			2,300			< 5			320		
1Q11	620,000			< 5,000			250,000			< 5,000			44			1,000			27			2,800			< 1			5.9		
2Q11	630,000			< 5,000			190,000			< 2,000			65			1,300			21			2,600			< 1			13		
3Q11	520,000			< 5,000			220,000		J	< 2,000		UJ	52			1,500			28			2,600			< 10			590		
4Q11	470,000			< 5,000			250,000			2,600			34			850			41			1,900			< 2			310		
1Q12	300,000			< 5,000			200,000			3,500			37			2,400			34			2,300			< 5			350		
2Q12	500,000			< 5,000			210,000			2,200			57			2,800			39			2,500			< 5			380		
3Q12	410,000	D		< 1,000			220,000			2,800			63			4,200			31			2,300			< 5			410		
4Q12	330,000			< 5,000			130,000			< 2,000			92			4,600			7.6			560			< 5			410		
1Q13	120,000			< 2,000			140,000			1,000			96			5,000									< 5			450		
2Q13	980,000			< 10,000			190,000			< 1,000			59			3,100			27			2,200			< 1			14		
3Q13	1,300,000			< 10,000			140,000			< 1,000			86			2,800			130			2,200			< 5			460		

Table 2
Groundwater Concentrations - 2006 through 2013
Benzene and Chlorobenzene
BSA and CPA Wells

Quarter	CPA-MW-1D						CPA-MW-2D						CPA-MW-3D						CPA-MW-4D						CPA-MW-5D					
	Benzene			Chlorobenzene			Benzene			Chlorobenzene			Benzene			Chlorobenzene			Benzene			Chlorobenzene			Benzene			Chlorobenzene		
	Result (µg/L)	Lab Qual	URS Qual	Result (µg/L)	Lab Qual	URS Qual	Result (µg/L)	Lab Qual	URS Qual	Result (µg/L)	Lab Qual	URS Qual	Result (µg/L)	Lab Qual	URS Qual	Result (µg/L)	Lab Qual	URS Qual	Result (µg/L)	Lab Qual	URS Qual	Result (µg/L)	Lab Qual	URS Qual	Result (µg/L)	Lab Qual	URS Qual	Result (µg/L)	Lab Qual	URS Qual
1Q06	6,500			24,000			1,600	D		30,000	D		11,000	D		1,400														
2Q06	2,900			16,000			2,200			32,000			580		J	320		J	73		J	1,400		J	< 1			1,200	D	
3Q06	3,300			19,000			2,200	D		38,000	D		500			520			82			1,400			< 1			1,500	D	
4Q06	3,800			16,000			1,500			28,000			3,500			680			180			1,100			< 57			2,600		J
1Q07	4,300			13,000			1,700			18,000			240			370			370			1,000	D		< 10			1,200		
2Q07	2,800			17,000			7,400			33,000			55			310			< 130			900			< 10			1,000		
3Q07	2,800			13,000			1,300			18,000			38			480			310	D		770	D		< 1			< 1		
4Q07	3,000			12,000			14,000			27,000			26			420			110	D		490	D		< 1			1,600	D	
1Q08	2,600			15,000			1,800			26,000			25			430			190		J	900		J	6.6			1,200	D	
2Q08	3,600			18,000			730			31,000			24			490			260			870								
3Q08	3,100			15,000			3,200			33,000			25		J	460		J	610	D		870	D		< 5			850		
4Q08	3,200			13,000			2,000			33,000			< 53			420	D		810			220			< 15			1,400		
1Q09	4,200			16,000			820			31,000			86			460			30			1,100			< 10			1,500		
2Q09	3,300			17,000			330			37,000			27			500			15			1,700	D		< 10			1,200		
3Q09	5,000			16,000			1,100			30,000			44			510	D		12			1,100			< 10			1,500		
4Q09	6,000			15,000			770			28,000			< 5			520			< 10			750			18			1,300		
1Q10	7,300			18,000			1,100			30,000			180			660			37			800			< 10			1,700		
2Q10	7,200			16,000			< 200			30,000			87			560			39			920			< 5			1,500	D	
3Q10	5,800			17,000			300			21,000			100			290			26			570			< 20			1,100		
4Q10	8,000			19,000			470			28,000			68			310			48			220			< 20			1,200		
1Q11	9,400			18,000			1,600			25,000			8			610			< 10			300			< 20			1,700		
2Q11	7,900			20,000			370			25,000			7.3			630			57			290			< 20			1,200		
3Q11	6,700		J	19,000		J	< 200			12,000			40			460			50		J	390		J	< 20			1,200		
4Q11	9,100			18,000			650			24,000			30			820			6			150			< 20			1,500		
1Q12	9,300			23,000			< 500			24,000			< 10			990			2.1			390			< 20			1,700		
2Q12	8,700			20,000			< 200			22,000			16			1,000			< 2			210			< 20			1,500		
3Q12	9,900			22,000	E	J	< 250			25,000			8.4			1,200	D		< 2			290			< 20			1,600		
4Q12	8,400			18,000			250			24,000			1,400			1,600			< 2			210			< 5			500		
1Q13	7,900			18,000			3,800			22,000			9,900			1,000			< 2			270			< 20			2,000		
2Q13	6,800			17,000			< 250			30,000			7,300			860			8.2			150			< 20			1,300		
3Q13	8,100			19,000			< 250			30,000			6,400			460			2.8			160			< 20			1,300		

Notes:
µg/L = micrograms per liter
< = Result is non-detect, less than the reporting limit given.
J = Estimated value
D = Compound analyzed at a dilution

See last page of table for notes.

Table 3
Geochemical Parameters
2008 through 2013
BSA and CPA Wells

Quarter	Sample Date	Dissolved Oxygen (mg/L)	ORP (mV)	Methane (ug/L)	Sulfate as SO4 (mg/L)	Nitrogen, Nitrate (mg/L)	Total Organic Carbon (mg/L)	Chloride (mg/L)	Conductivity (ms/cm)	Ferrous Iron (mg/L)	pH (SU)	Temperature (°C)
BSA-MW-1S												
3Q08	08/26/08	0.57	-145	10,000	130	<0.05	8.8	95	1.956	1.17	7.32	20.10
4Q08	11/20/08	6.87	-131	5,800	<5	<0.05	7.6	110	1.875	1.75	7.26	14.56
1Q09	03/02/09	10.24	-151	11,000	<5	<0.25	6.9	100	1.687	0.75	7.29	14.30
2Q09	06/04/09	0.75	-77	5,500	<5	<0.05	8.3	110	1.99	0.46	7.18	17.99
3Q09	08/20/09	4.55	-142	13,000	<5	<0.05	9.7	100	1.871	1.36	7.25	17.93
4Q09	11/18/09	1.57	-155	15,000	<5	<0.05	6.5	99	1.637	2.07	7.49	15.18
1Q10	02/17/10	0.06	-146	8,700	<5	<0.05	8.4	100	1.856	1.17	7.23	13.99
2Q10	05/19/10	0.60	123	8,400	<5	<0.05	9.7	100 J	1.816	0.82	7.41	16.02
3Q10	09/22/10	0.00	-137	9,100	<5	<0.05	7.6	150	1.91		5.99	18.55
4Q10	12/06/10	0.00	-180	6,600	<5	<0.05	6.1	170	0.23	3.37	7.16	12.28
1Q11	02/23/11	0.00	100	11,000	<5	<0.05	6.3	230	0.24	2.07	7.28	14.59
2Q11	05/18/11	0.00	-139	6,800	<5	<0.05	7	190	2.02	1.01	8.17	14.53
3Q11	08/15/11	0.00	-160	7,600	<50	<0.05	6.9	240	2.105	1.79	7.37	17.76
4Q11	11/15/11	0.06	-170	8,200	<5	<0.05	6.6	250	2.102	3.12	7.27	17.88
1Q12	02/15/12	0.02	-155	16,000	<50	<0.05	5.4	180	1.605	0.02	7.2	15.84
2Q12	05/16/12	0.48	-116	10,000	<5	<0.05	7.1	120	1.556	>3.3	6.91	17.51
3Q12	08/16/12	-0.10	-200	9,700	<5	<0.05	6	140	1.552	>3.3	7.25	19.57
4Q12	11/14/12	-0.07	-23	7,600	<5	<0.05	8.9	110	1.588	>3.3	7.15	20.12
1Q13	02/25/13	0.09	-162	9,300	<5	<0.05	7.7 J	100	1.803	>3.3	7.15	18.63
2Q13	05/15/13	-0.05	-171	17,000	<5	<0.05	6.7	87	1.775	>3.3	7.19	20.38
3Q13	08/08/13	-0.05	-163	12,000	130	<0.05	8.5	97	1.913	>3.3	7.17	19.42

See last page of table for notes.

Table 3
Geochemical Parameters
2008 through 2013
BSA and CPA Wells

Quarter	Sample Date	Dissolved Oxygen (mg/L)	ORP (mV)	Methane (ug/L)	Sulfate as SO4 (mg/L)	Nitrogen, Nitrate (mg/L)	Total Organic Carbon (mg/L)	Chloride (mg/L)	Conductivity (ms/cm)	Ferrous Iron (mg/L)	pH (SU)	Temperature (°C)
BSA-MW-2D												
3Q08	08/21/08	0.06	36	3,600	130	<0.05	5.4	98	1.485	2.39	6.9	18.86
4Q08	11/24/08	5.80	-112	3,300	110	<0.05	4.8	94	1.73	1.63	7.33	15.39
1Q09	02/26/09	7.13	-166	3,200	160	<0.05	4.9	93	1.832	0.39	7.18	15.87
2Q09	06/03/09	0.55	-79	20,000	<5	0.073	5.4	90	1.41	0.1	6.94	15.66
3Q09	08/19/09	1.18	-136	11,000	<5	<0.05	6.6	85	1.548	1.14	6.98	19.61
4Q09	11/17/09	1.12	-161	15,000	<5	<0.05	5.1	90	1.41	1.64	7.19	15.19
1Q10	02/16/10	0.09	-161	9,100	<5	<0.05	5.6	93	1.543	1.87	7.08	15.93
2Q10	05/25/10	6.45	-93	28,000	<5	<0.05	5.5	92	1.57	2.74	6.8	17.92
3Q10	09/22/10	4.67	-93	17,000	<5	<0.05	5.9	94	0.006		5.58	16.44
4Q10	12/06/10	0.00	-151	7,100	<5	<0.05	6.2	98	0.17	2.4	7.02	14.88
1Q11	02/22/11	0.00	124	12,000	<5	<0.05	6.2	95	0.17	2.58	6.84	15.67
2Q11	05/18/11	0.00	-179	13,000	<5	<0.05	5.2	98	1.46	1	7.8	16.43
3Q11	08/16/11	0.01	-191	7,100	<5	<0.05	6	110	1.485	>3.3	6.9	18.78
4Q11	11/16/11	0.02	-200	4,500	<5	<0.05	6.3	100	1.519	2.72	7.05	16.53
1Q12	02/14/12	0.05	-139	5,100	<5	<0.05	6.6	97	1.29	2.44	7.02	15.23
2Q12	05/15/12	0.37	-117	9,500	<5	<0.05	5.8	95	1.324	2.61	7.08	17.58
3Q12	08/15/12	-0.09	-140	12,000	<5	<0.05	6	98	1.287	2.85	7.03	18.21
4Q12	11/13/12	-0.12	-170	8,900	<5	<0.05	7.6	92	1.357	1.61	7.15	16.95
1Q13	02/19/13	0.09	-135	8,500	<5	<0.05	6	93	1.517	3.18	7.11	16.06
2Q13	05/14/13	0.04	-132	14,000	<5	<0.05	5.7	91	1.472	>3.3	7.03	18.50
3Q13	08/06/13	-0.01	-139	8,600	<5	<0.05	6.1	92	1.521	3.05	7.25	18.36

See last page of table for notes.

Table 3
Geochemical Parameters
2008 through 2013
BSA and CPA Wells

Quarter	Sample Date	Dissolved Oxygen (mg/L)	ORP (mV)	Methane (ug/L)	Sulfate as SO4 (mg/L)	Nitrogen, Nitrate (mg/L)	Total Organic Carbon (mg/L)	Chloride (mg/L)	Conductivity (ms/cm)	Ferrous Iron (mg/L)	pH (SU)	Temperature (°C)
BSA-MW-3D												
3Q08	08/25/08	0.06	-125	250	230	<0.05	5.2	82	1.559	>5	6.91	18.69
4Q08	11/21/08	6.48	-103	320	260	<0.05	3.8	73	1.602	>5	8.28	15.22
1Q09	03/02/09	9.23	-139	540	240	<0.25	3.7	64	1.517	>5	6.82	14.08
2Q09	06/04/09	0.84	-109	320	200	<0.5	4.7	74	1.517	>5	6.75	16.72
3Q09	08/19/09	2.54	-135	440	260	<0.05	4.8	67	3.08	>5	6.84	18.61
4Q09	11/17/09	1.40	-128	400	240	<0.05	8.1	69	1.472	>5	7.01	14.81
1Q10	02/16/10	0.15	-149	290	170	<0.05	3.5	71	1.464	>5	6.86	14.13
2Q10	05/25/10	4.30	-105	380	260	<0.05	3.6	72	1.566	3.44	6.85	17.12
3Q10	09/22/10	1.96	-112	240	270	<0.05	4.4	76	1.57		5.71	18.02
4Q10	12/03/10	0.00	-149	240	230	<0.05	4	67	0.18	4.66	7.13	14.50
1Q11	02/22/11	0.00	81	1,600	130	<0.05	3.6	120	0.19	2.85	6.7	14.31
2Q11	05/18/11	1.88	-98	230	200	<0.05	3.7	78	1.49	1.45	7.62	16.12
3Q11	08/16/11	0.07	-139	190	230	<0.05	4.8	90	1.57	>3.3	7.02	17.54
4Q11	11/15/11	-0.04	-102	970	96	<0.05	3.8	120	1.51	>3.3	6.95	17.34
1Q12	02/14/12	0.03	-123	2,200	69	<0.05	3.9	130	1.321	2.66	6.85	15.43
2Q12	05/15/12	0.36	-98	940	86	<0.05	3.7	120	1.345	>3.3	6.85	17.75
3Q12	08/14/12	-0.02	-120	330	94	<0.05	4.8	110	1.331	>3.3	6.84	18.10
4Q12	11/13/12	-0.08	-130	2,700	88	<0.05	7.5	110	1.356	>3.3	6.64	17.77
1Q13	02/19/13	0.11	-126	2,400	67	<0.05	5.9	110	1.483	>3.3	6.87	16.53
2Q13	05/15/13	0.06	-124	1,800	43	<0.05	3.5	130	1.449	>3.3	6.92	18.75
3Q13	08/06/13	0.02	-120	1,400	59	<0.05	4	130	1.475	>3.3	7.07	17.78

See last page of table for notes.

Table 3
Geochemical Parameters
2008 through 2013
BSA and CPA Wells

Quarter	Sample Date	Dissolved Oxygen (mg/L)	ORP (mV)	Methane (ug/L)	Sulfate as SO4 (mg/L)	Nitrogen, Nitrate (mg/L)	Total Organic Carbon (mg/L)	Chloride (mg/L)	Conductivity (ms/cm)	Ferrous Iron (mg/L)	pH (SU)	Temperature (°C)
BSA-MW-4D												
3Q08	08/25/08	0.48	-118	170	85	<0.05	4.7	120	1.61	>5	6.86	16.86
4Q08	11/20/08	5.85	-87	84	130	<0.05	5.5	120	1.673	>5	6.82	13.63
1Q09	02/25/09	6.28	-123	110	130	<0.05	5.4	120	1.538	>5	6.92	15.95
2Q09	06/04/09	0.88	-91	330	<5	<0.5	4.7	170	1.509	>5	6.71	15.99
3Q09	08/18/09	1.11	-172	270	120	<0.05	7	100	1.337	4.23	6.8	17.94
4Q09	11/16/09	1.19	-103	140	100	<0.05	4.7	110 J	1.225	>5	6.97	14.49
1Q10	02/16/10	0.20	-155	220	120	<0.05	5.8	120	1.668	>5	6.79	14.77
2Q10	05/20/10	0.39	164	86	45	<0.05	4.9	150	1.749	>5	6.91	15.82
3Q10	09/22/10	0.29	-111	44	53	0.9	5.4	160	1.79		5.67	16.72
4Q10	12/03/10	0.00	-237	200	29	<0.05	4.8	160	0.19	>5	7.08	16.03
1Q11	02/21/11	0.00	-13	48	130	<0.05	5.7	110	0.19	1.44	6.79	13.37
2Q11	05/17/11	2.46	-184	70	64	<0.05	5.6	130	1.71	2.61	7.28	15.01
3Q11	08/17/11	0.03	-180	150	66	<0.05	6.4	150	1.656	2.94	6.96	17.56
4Q11	11/16/11	0.06	-142	64	120	0.071	5.7	110 J	1.622	2.18	6.95	15.43
1Q12	02/13/12	0.04	0	170	85		6.5	130	1.262	>3.3	6.99	14.77
2Q12	05/14/12	0.43	-80	110	74	<0.05	5.1	230	1.342	>3.3	6.86	16.97
3Q12	08/14/12	-0.02	-110	330	60	<0.05	7.4	130 J	1.299	>3.3	6.89	16.88
4Q12	11/12/12	-0.03	-134	280	130	<0.05	7.4	93	1.282	>3.3	6.95	16.29
1Q13	02/19/13	0.19	-113	280	210	<0.05	4.6	94	1.549	>3.3	6.94	16.22
2Q13	05/13/13	0.25	-128	350	75	<0.05	4.2	120	1.562	>3.3	6.96	16.53
3Q13	08/05/13	0.04	-114	250	99	<0.05	4.8	100	1.402	>3.3	7.01	17.17

See last page of table for notes.

Table 3
Geochemical Parameters
2008 through 2013
BSA and CPA Wells

Quarter	Sample Date	Dissolved Oxygen (mg/L)	ORP (mV)	Methane (ug/L)	Sulfate as SO4 (mg/L)	Nitrogen, Nitrate (mg/L)	Total Organic Carbon (mg/L)	Chloride (mg/L)	Conductivity (ms/cm)	Ferrous Iron (mg/L)	pH (SU)	Temperature (°C)
BSA-MW-5D												
3Q08	08/20/08	0.16	-2	1,300	51	<0.05	5.1	290	2.093		6.22	18.80
4Q08	11/21/08	6.68	-100	5,700	<10	<0.05	5.9	310	2.412	>5	8.22	13.32
1Q09	02/25/09	5.27	-172	13,000	<5	<0.05	5.7	270	2.119	>5	6.92	16.68
2Q09	06/09/09	3.13	-84	310	65	<0.05	5.1	270	2.399	>5	6.8	17.65
3Q09	08/26/09	2.33	-130	11,000	<5	<0.25	6.3	270	2.329	>5	6.74	18.63
4Q09	11/16/09	1.13	-69	12,000	<5	<0.05	5.3	290	2.147	>5	6.98	16.20
1Q10	02/15/10	0.12	-153	14,000	<5	<0.05	5.7	300	2.465	>5	6.85	14.50
2Q10	05/24/10	0.53	-139	3,500	<5	<0.05	4.9	190	1.951	>5	6.79	18.79
3Q10	09/21/10	0.16	-112	5,100	69	<0.05	6.1	260	2.3		6.57	20.72
4Q10	12/02/10	0.00	-128	7,000	21	<0.05	5.4	270	0.25	>5	7.06	13.88
1Q11	02/21/11	0.00	-118	8,100	63	<0.05	5.3	87	0.2	2.58	6.85	14.71
2Q11	05/17/11	0.00	-79	1,900	44	0.091	5.5	110	3.13	4.12	6.68	14.97
3Q11	08/17/11	0.02	-121	54	380	<0.05	5	250	2.535	>3.3	6.96	19.50
4Q11	11/16/11	-0.04	-65	5,500	<5	<0.05	5.7	290	2.213	2.44	7	17.81
1Q12	02/13/12	0.08	-139	6,900	<5		5.6	260	1.79	>3.3	7.01	14.81
2Q12	05/14/12	0.38	-134	14	140	<0.05	5.8	110	1.847	>3.3	6.93	17.77
3Q12	08/14/12	-0.04	-130	22,000	<5	<0.05	5.6	310	1.998	>3.3	6.94	18.48
4Q12	11/12/12	-0.08	-157	19,000	<5	<0.05	7.4	320	2.035	>3.3	6.96	17.20
1Q13	02/18/13	0.07	-133	20,000	<5	<0.05	6.9	320	2.275	>3.3	7	16.46
2Q13	05/14/13	0.09	-145	1,200	100	<0.05	5.2	130	1.621	>3.3	6.89	18.28
3Q13	08/05/13	0.05	-121	7,300	<5	<0.05	5.8	310	2.208	>3.3	6.99	18.48

See last page of table for notes.

Table 3
Geochemical Parameters
2008 through 2013
BSA and CPA Wells

Quarter	Sample Date	Dissolved Oxygen (mg/L)	ORP (mV)	Methane (ug/L)	Sulfate as SO4 (mg/L)	Nitrogen, Nitrate (mg/L)	Total Organic Carbon (mg/L)	Chloride (mg/L)	Conductivity (ms/cm)	Ferrous Iron (mg/L)	pH (SU)	Temperature (°C)
CPA-MW-1D												
3Q08	08/26/08	-0.01	-21	21,000	14	<0.5	16	200	2.648	0	9.37	22.49
4Q08	11/20/08	0.25	3	15,000	13	<0.5	16	180	2.463	0.56	9.54	14.33
1Q09	03/02/09	9.26	-124	30,000	5.7	<0.5	12	130	2.18	0.19	9.24	15.57
2Q09	06/08/09	0.95	40	28,000	15	<0.5	61	150	2.46	0.46	9.04	18.34
3Q09	08/20/09	2.49	12	32,000	<5	<0.05	58	110	2.319	0.27	9.17	19.55
4Q09	11/18/09	0.62	-197	32,000	7.7	<0.05	17	120	2.076	0.87	9.47	16.66
1Q10	02/17/10	0.02	-67	23,000	5.7	<0.05	12	120	2.169	0.69	9.17	14.39
2Q10	05/20/10	0.21	248	17,000	12	<0.5	12	110	2.019	0.26	9.25	16.53
3Q10	09/23/10	0.00	-64	18,000	<100	<1	15	140	2.39		8	18.44
4Q10	12/07/10	0.00	-125	17,000	15	<0.05	16	130	2.3	2.46	9.17	15.79
1Q11	02/23/11	0.00	-114	18,000	<5	<0.05	13	120	0.22	0.46	9.13	13.89
2Q11	05/17/11	0.95	-152	15,000	13	<0.05	12	120	1.72	2.38	7.2	17.44
3Q11	08/15/11	0.00	-122	13,000	15	<0.5	25	140	2.187	>3.3	9.36	18.63
4Q11	11/15/11	-0.01	-219	13,000	11	<0.05	19	150	2.078	0	8.91	17.81
1Q12	02/15/12	0.01	-168	15,000	6.6	<0.05	12	140	1.838	<0.03	8.8	16.57
2Q12	05/16/12	0.37	-154	18,000	6.3	<0.05	19	130	1.79	<0.03	8.06	18.05
3Q12	08/16/12	-0.15	-110	14,000	<5	<0.05	12	150	1.803	<0.03	8.84	19.32
4Q12	11/14/12	-0.21	-65	13,000	<5	<0.05	13	170	1.796	<0.03	8.78	17.72
1Q13	02/25/13	0.00	-123	13,000	<5	<0.05	11 J	150	2.036	<0.03	8.73	17.08
2Q13	05/16/13	-0.01	-77	19,000	<5	<0.05	11	120	1.939	0.44	8.88	18.47
3Q13	08/08/13	-0.05	-87	17,000	<5	0.095	11	130	1.961	<0.03	8.81	18.96

See last page of table for notes.

Table 3
Geochemical Parameters
2008 through 2013
BSA and CPA Wells

Quarter	Sample Date	Dissolved Oxygen (mg/L)	ORP (mV)	Methane (ug/L)	Sulfate as SO4 (mg/L)	Nitrogen, Nitrate (mg/L)	Total Organic Carbon (mg/L)	Chloride (mg/L)	Conductivity (ms/cm)	Ferrous Iron (mg/L)	pH (SU)	Temperature (°C)
CPA-MW-2D												
3Q08	08/26/08	6.46	-106	7,400 J	<5	<0.05	12	130	1.582		6.89	21.37
4Q08	11/20/08	6.92	105	1,400	<5	<0.05	11	85	1.396	4.85	6.92	17.03
1Q09	03/02/09	13.43	-144	2,800	<5	<0.25	11	67	1.327	>5	6.86	16.23
2Q09	06/08/09	1.66	-51	7,200	<5	<0.05	12	92	1.363	4.78	6.81	18.26
3Q09	08/20/09	4.39	-111	2,800	<5	<0.05	12	66	1.421	>5	6.78	19.91
4Q09	11/18/09	1.75	-126	2,600	<5	<0.05	11	67	1.23	>5	7.05	16.89
1Q10	02/17/10	0.19	-123	2,200	<5	<0.05	11	63	1.307	>5	6.91	16.29
2Q10	05/20/10	0.54	170	1,800 H J	<5	<0.05	12	76	1.352	4.86	6.95	17.69
3Q10	09/23/10	0.21	-91	5,900	<5	<0.05	11	70	1.37		5.32	18.64
4Q10	12/07/10	0.00	-111	2,500	<5	<0.05	11	54	1.04	>5	7.06	16.94
1Q11	02/23/11	0.00	-67	2,500	<5	<0.05	11	560	0.33	2.63	6.93	16.72
2Q11	05/19/11	0.04	-88	3,200	<50	<0.05	12	80	2.17	0.41	9.5	15.81
3Q11	08/15/11	0.05	-132	3,600	<5	<0.05	12	65	1.275		6.98	20.49
4Q11	11/15/11	0.09	-142	1,300	21	<0.05	11	60	1.28	3.18	6.97	19.00
1Q12	02/15/12	0.08	-71	1,300	37	<0.05	11	51	1.044	>3.3	6.82	17.19
2Q12	05/16/12	0.45	-88	1,400	38	<0.05	10	45	1.076	>3.3	7.02	18.89
3Q12	08/16/12	-0.10	-130	990	37	<0.05	9.3	52	1.069	>3.3	6.96	19.88
4Q12	11/14/12	-0.01	-35	700	53	<0.05	11	51	1.077	>3.3	6.96	18.09
1Q13	02/25/13	0.04	-90	860	55	<0.05	8.1	230	1.871	>3.3	6.85	17.57
2Q13	05/16/13	0.04	-108	2,300	38	<0.05	9.5	67	1.262	2.48	6.93	18.56
3Q13	08/08/13	-0.01	-113	1,500	41	<0.05	9.4	55	1.173	>3.3	6.99	19.82

See last page of table for notes.

Table 3
Geochemical Parameters
2008 through 2013
BSA and CPA Wells

Quarter	Sample Date	Dissolved Oxygen (mg/L)	ORP (mV)	Methane (ug/L)	Sulfate as SO4 (mg/L)	Nitrogen, Nitrate (mg/L)	Total Organic Carbon (mg/L)	Chloride (mg/L)	Conductivity (ms/cm)	Ferrous Iron (mg/L)	pH (SU)	Temperature (°C)
CPA-MW-3D												
3Q08	08/21/08	0.29	2	8,800	<25	<0.05	6.7	440	2.182	>5	6.69	19.75
4Q08	11/24/08	6.09	-87	33,000	<5	<0.05	7.9	390	2.465	>5	6.95	13.75
1Q09	02/26/09	6.15	-151	30,000	<5	<0.05	8.9	280	2.147	>5	6.79	16.88
2Q09	06/03/09	0.56	-105	31,000	<5	<0.05	9.1	290	1.819	>5	6.77	16.48
3Q09	08/19/09	3.66	-137	32,000	<5	<0.05	11	270	2.177	>5	6.46	22.09
4Q09	11/17/09	1.57	-131	36,000	<5	<0.05	8.5	290	1.973	4.56	6.85	15.61
1Q10	02/18/10	0.09	-138	26,000	<5	<0.05	9.9	240	2.007	>5	6.64	14.59
2Q10	05/26/10	0.26	-98	15,000	<5	<0.05	11	160	1.692		6.78	18.61
3Q10	09/22/10	0.07	-115	15,000	<5	<0.05	11	200	1.79		5.56	19.39
4Q10	12/06/10	0.00	-149	7,100	<50	<0.05	11	160	0.2	>5	6.79	15.46
1Q11	02/22/11	0.00	-88	8,400	13	<0.05	11	120	0.17	2.53	6.71	16.01
2Q11	05/18/11	0.00	-124	2,300	48	<0.05	10	110	1.35	1.4	7.51	17.19
3Q11	08/16/11	0.04	-185	1,500	<5	<0.05	10	110	1.427		6.99	18.73
4Q11	11/16/11	0.01	-239	1,600	53	<0.05	8	130	1.531	2.11	7.02	17.18
1Q12	02/14/12	0.03	-80	1,300	51	<0.05	8.6	100	1.115	>3.3	6.79	16.57
2Q12	05/15/12	0.37	-137	6,200	<5	<0.05	9	96	1.232	>3.3	7.05	18.54
3Q12	08/15/12	-0.10	-140	3,500	<5	<0.05	8.6	98	1.241	>3.3	6.98	19.18
4Q12	11/13/12	-0.10	-160	15,000	<5	<0.05	11	140	1.446	>3.3	6.88	18.15
1Q13	02/19/13	0.10	-121	23,000	<5	<0.05	8.6	360	2.263	>3.3	6.85	17.39
2Q13	05/14/13	-0.04	-123	19,000	<5	<0.05	8.4	340	2.173	>3.3	6.86	19.24
3Q13	08/06/13	0.01	-121	18,000	<5	<0.05	8.9	340	2.145	>3.3	7.02	19.87

See last page of table for notes.

Table 3
Geochemical Parameters
2008 through 2013
BSA and CPA Wells

Quarter	Sample Date	Dissolved Oxygen (mg/L)	ORP (mV)	Methane (ug/L)	Sulfate as SO4 (mg/L)	Nitrogen, Nitrate (mg/L)	Total Organic Carbon (mg/L)	Chloride (mg/L)	Conductivity (ms/cm)	Ferrous Iron (mg/L)	pH (SU)	Temperature (°C)
CPA-MW-4D												
3Q08	08/25/08	0.63	-148	12,000	<5	<0.05	5.8	280	2.233	>5	6.96	17.91
4Q08	11/21/08	6.39	-112	9,000	<5	<0.05	6	310	2.39	>5	8.3	15.63
1Q09	02/25/09	4.95	-172	4,800	72	<0.05	5.6	240	2.145	>5	6.95	16.61
2Q09	06/03/09	0.73	-117	3,200	<5	0.19	5.7	240	1.854	>5	6.97	16.50
3Q09	08/18/09	0.83	-155	5,300	<5	<0.05	8.5	250	1.849	>5	6.68	18.02
4Q09	11/16/09	1.40	-168	5,100	36	<0.05	5.6	250	2.144	>5	7.04	15.55
1Q10	02/15/10	0.20	-148	6,000	<5	<0.05	6.8	290	2.464	>5	6.83	13.76
2Q10	05/24/10	6.80	103	4,000	<5	<0.05	6	270	2.246	>5	6.86	18.15
3Q10	09/22/10	0.02	-118	9,900	<5	<0.05	6.5	280	2.35		5.7	16.67
4Q10	12/03/10	0.00	-143	9,100	<5	<0.05	10	270	0.25	4.71	7.11	13.67
1Q11	02/22/11	0.00	-95	17,000	<5	<0.05	6.5	320	0.28	1.24	6.72	14.49
2Q11	05/17/11	0.00	-136	4,800	<5	<0.05	5.8	290	1.42	1.79	7.54	17.36
3Q11	08/17/11	0.00	-137	8,700	<5	<0.05	5.9	300	2.25	>3.3	6.99	18.50
4Q11	11/17/11	0.02	-123	8,500	<50	<0.05	8	300	2.332	>3.3	7.01	18.11
1Q12	02/13/12	-0.08	-162	16,000	<5		6.9	350	2.031	>3.3	7.03	15.78
2Q12	05/14/12	0.33	-136	22,000	<5	<0.05	8.9	290	1.898	>3.3	6.96	17.54
3Q12	08/14/12	-0.05	-140	25,000	<5	<0.05	8.9	230	1.677	>3.3	6.95	17.82
4Q12	11/12/12	0.03	-161	4,100	<5	<0.05	10	110	1.193	>3.3	7.06	16.34
1Q13	02/18/13	0.15	-138	2,000	<5	<0.05	7.3	96	1.291	>3.3	7.05	15.86
2Q13	05/14/13	-0.01	-142	12,000	<5	<0.05	9.4	160	1.656	>3.3	7.05	18.13
3Q13	08/05/13	-0.01	-140	11,000	<5	<0.05	8.8	180	1.64	>3.3	7.05	17.33

Table 3
Geochemical Parameters
2008 through 2013
BSA and CPA Wells

Quarter	Sample Date	Dissolved Oxygen (mg/L)	ORP (mV)	Methane (ug/L)	Sulfate as SO4 (mg/L)	Nitrogen, Nitrate (mg/L)	Total Organic Carbon (mg/L)	Chloride (mg/L)	Conductivity (ms/cm)	Ferrous Iron (mg/L)	pH (SU)	Temperature (°C)
CPA-MW-5D												
3Q08	08/26/08	1.28	-86	55	1,600	<0.5	3.9	300	3.479	>5	6.38	17.69
4Q08	11/24/08	6.26	-73	52	1,500	<0.05	3.6	330	3.798	>5	6.52	14.59
1Q09	02/26/09	6.37	-95	44	1,400	<0.05	3.6	280	3.73	>5	6.4	14.73
2Q09	06/02/09	0.68	-39	42	1,700 J	<0.5	4	300	3.098	>5	6.15	16.02
3Q09	08/26/09	1.62	-38	30	1,600	<0.25	4	290	3.807	>5	5.42	16.23
4Q09	11/19/09	6.22	-127	27	1,600	<0.05	3.5	310	3.671	>5	6.47	13.70
1Q10	02/16/10	0.11	-109	21	1,500	<0.05	3.4	350	4	>5	6.33	13.10
2Q10	06/03/10	6.47	-53	13	1,800	0.058	3.6	290	3.707		6.28	13.96
3Q10	09/21/10	0.79	-93	13	1,700	<0.05	4.4	280	3.8		5.98	16.71
4Q10	12/02/10	4.55	105	14	1,400	<0.05	3.8	300	0.4	>5	6.57	13.06
1Q11	02/21/11	0.00	53	9.2	1,600	<0.05	4	330	0.4	3.08	6.51	13.63
2Q11	05/17/11	0.36	-130	10	930	<0.05	4.2	340	2.24	3.38	7.22	17.04
3Q11	08/16/11	0.36	-109	10	1,500	<0.05	3.9	310	3.734	>3.3	6.49	16.19
4Q11	11/16/11	-0.03	-2	12	670	0.24	3.5	320	2.85	3.16	6.57	15.23
1Q12	02/14/12	0.14	-97	11	590	<0.05	3.7	290	2.191	>3.3	6.49	14.02
2Q12	05/15/12	0.35	-73	11	900	<0.05	3.4	280	2.332	>3.3	6.63	15.52
3Q12	08/13/12	-0.01	-90	17	250	<0.05	4	220	1.66	>3.3	6.62	16.17
4Q12	11/12/12	0.00	-140	17	120	<0.05	5.2	180	1.398	>3.3	6.65	15.46
1Q13	02/18/13	0.14	-80	25	230	<0.05	4.1	200	1.65	>3.3	6.72	15.79
2Q13	05/15/13	0.13	-85	11	340	<0.05	3.7	200	2.023	>3.3	6.58	17.28
3Q13	08/05/13	0.03	-81	12	490	<0.05	4	180	2.049	>3.3	6.54	16.01

Notes:
µg/L = micrograms per liter
mg/L = milligrams per liter
ms/cm = microsiemens per centimeter
mV = millivolts
SU = Standard units
< = Result is non-detect, less than the reporting limit given.
> = Ferrous iron result exceeds the upper limit of the field colorimeter
J = Estimated detected value
H = Prepped or analyzed outside of specified holding time
DO, ORP, Temperature, Conductivity, and pH were measured in the field using a multi-parameter water quality meter with a flow-thru cell. Values presented represent final measurements before sampling.
Ferrous Iron readings were measured in the field using a Hach DR-890 Colorimeter after the groundwater passed through a 0.2 µm filter
A blank space indicates sample not analyzed for select analyte

Table 4a.
Summary of Phospholid Fatty Acids (PLFA) Data Analysis

	Sampling Quarter																			
Monitoring Location	**3Q08**	**4Q08**	**1Q09**	**2Q09**	**3Q09**	**4Q09**	**1Q10**	**4Q10**	**4Q10**	**1Q11**	**2Q11**	**3Q11**	**4Q11**	**1Q12**	**2Q12**	**3Q12**	**4Q12**	**1Q13**	**2Q13**	**3Q13**
Total Biomass (cells/bead)																				
BSA-MW-1S	4.4E+05	1.1E+05	8.2E+04	1.7E+05	1.1E+05	4.6E+05	3.3E+05	9.9E+05	4.4E+05	3.7E+05	4.9E+04	1.0E+06	-	1.1E+05	9.0E+04	9.3E+04	5.9E+04	2.0E+05	2.0E+04	6.4E+04
BSA-MW-2D	3.7E+04	1.1E+05	3.4E+04	1.7E+05	1.3E+05	6.8E+04	1.9E+04	4.6E+05	2.1E+05	2.2E+05	1.3E+05	2.1E+05	3.9E+04	3.3E+05	9.0E+04	9.0E+04	6.1E+04	1.6E+05	1.9E+04	-
BSA-MW-3D	4.5E+04	2.4E+04	7.5E+04	1.4E+05	8.1E+04	3.0E+04	1.8E+04	3.1E+05	1.3E+05	8.0E+04	1.7E+05	4.9E+04	4.3E+04	8.9E+04	5.6E+03	2.0E+04	1.9E+04	5.3E+04	2.4E+04	1.9E+04
BSA-MW-4D	1.0E+05	7.1E+04	3.0E+04	1.3E+05	7.9E+05	8.6E+04	6.4E+04	2.5E+05	1.6E+05	7.2E+05	7.9E+04	1.5E+04	3.9E+04	8.1E+04	8.6E+03	5.3E+03	1.2E+04	9.8E+04	1.0E+04	2.0E+04
BSA-MW-5D	2.3E+04	1.3E+05	4.3E+04	1.9E+05	1.5E+05	5.0E+04	3.7E+04	3.4E+05	1.1E+05	2.3E+05	7.2E+04	6.4E+04	1.5E+05	1.3E+05	2.1E+04	2.8E+05	5.0E+04	1.2E+05	3.4E+04	2.5E+04
CPA-MW-1D	3.1E+04	2.2E+05	1.2E+05	2.1E+04	1.8E+05	3.7E+04	4.4E+04	7.9E+04	5.6E+04	9.5E+04	1.2E+05	6.5E+04	8.6E+04	4.5E+04	2.6E+04	9.0E+03	2.2E+04	1.1E+05	4.0E+05	3.7E+04
CPA-MW-2D	1.6E+05	4.8E+04	8.2E+04	5.7E+04	2.3E+05	2.5E+04	2.3E+04	2.3E+05	4.6E+05	2.3E+05	1.9E+05	2.1E+05	7.6E+03	4.6E+04	8.0E+03	3.2E+03	2.1E+03	9.4E+04	2.6E+05	7.6E+04
CPA-MW-3D	2.5E+04	5.4E+04	9.3E+04	5.0E+04	2.8E+05	5.4E+04	1.2E+05	5.5E+05	1.8E+05	7.9E+05	7.1E+04	3.1E+05	3.4E+04	4.9E+04	2.7E+04	3.8E+04	3.6E+04	1.2E+05	6.6E+04	-
CPA-MW-4D	8.5E+05	2.3E+05	9.5E+04	1.6E+05	1.6E+06	2.8E+04	4.4E+04	2.5E+05	4.2E+05	2.4E+06	6.1E+05	2.9E+04	4.8E+04	1.0E+05	8.3E+03	3.5E+03	1.0E+04	7.1E+03	8.1E+04	1.8E+04
CPA-MW-5D	1.0E+06	8.7E+04	6.2E+04	2.6E+04	5.5E+04	1.1E+05	2.4E+04	6.7E+04	6.5E+05	5.7E+04	4.3E+04	1.7E+04	1.8E+04	2.8E+04	2.8E+03	2.3E+03	1.9E+03	1.1E+04	9.8E+03	2.0E+04
Site-Wide Average of Total Biomass:	**1.9E+05**																			
Biomass availability:	**Moderate**																			
Proteobacteria (%)																				
BSA-MW-1S	86.35	67.32	55.62	39.74	55.4	68.51	76.48	50.58	43.3	14.16	23.71	7.32	-	50.48	68.08	73.24	60.46	72.85	71.21	55.92
BSA-MW-2D	68.71	67.01	63.08	65.74	62.62	55.02	80.53	82.13	67.55	50.1	69.68	72.69	82.74	78.15	80.61	68.8	81.93	84.02	91.05	-
BSA-MW-3D	45.99	63.91	63.22	56.87	58.9	40.76	71.94	56.69	41.35	52.07	76.92	68.55	77.2	59.77	73.53	90	59.73	73.3	57.68	69.17
BSA-MW-4D	83.45	74.61	68.54	53.88	84.7	57.59	75.4	64.87	52.64	53.97	71.51	64.86	57.48	72.86	81.04	43.45	72.19	35.35	41.6	68.3
BSA-MW-5D	60.44	79.3	66.11	55.26	63.65	55.99	62.89	62.43	45.14	67.52	63.99	69.98	52.25	79.21	77.6	43.98	85.19	80.58	76.63	80.03
CPA-MW-1D	71.13	75.5	58.6	44.39	49.76	51.03	66.83	53.29	25.61	65.61	54.73	58.63	89.47	74.4	74.23	63.64	73.59	53.26	60.59	58.17
CPA-MW-2D	85.91	73.67	64.76	50.31	60.49	43.59	72.14	56.72	39.88	68.84	68.37	36.57	57.01	75.49	68.85	73.03	59.49	71.8	75.49	49.2
CPA-MW-3D	60.32	72	63.06	60.38	54.6	54.46	75.14	55.51	50.74	53.71	72.27	69.45	79.97	75.31	83.05	72.01	61.9	71.44	72.56	-
CPA-MW-4D	87.39	80.87	72.08	58.62	60.9	62.59	73.75	61.98	52.8	57.76	61.28	74.91	66.29	62.63	64.59	54.56	59.6	67.28	77.25	70.85
CPA-MW-5D	87.92	72.92	62.99	50.95	62.86	75.2	57.42	54.21	62.18	53.04	55.87	62.36	58.24	66.64	63.51	58.6	49.12	100	82.3	71.1
Site-Wide Average of Proteobacteria:	**6.3E+01**																			
Decreased Permeability (ratio trans/cis)																				
BSA-MW-1S	0.23	0.21	0.59	0.42	0.71	0.36	0.78	0.89	0.86	0.77	0	0.25	-	0.03	0.04	0	0.12	0.13	0	0.71
BSA-MW-2D	0.08	0.11	0.12	0.18	0.23	0.52	0	0.20	0.21	0.12	0.14	0.09	0.24	0.19	0.12	0	0	0.12	0	-
BSA-MW-3D	0	0.12	0.16	0.26	0.17	0.40	0	0.48	0.24	0.07	0.05	0	0	0.17	0	0	0	0	0	0
BSA-MW-4D	0.17	0.09	0.05	0.65	0.37	0.51	0	0.38	0.42	0.10	0.06	0	0.25	0.22	0	0	0	0.09	0	0
BSA-MW-5D	0	0.11	0.16	0.23	0.04	0.35	0	0.32	0.13	0.10	0	0	0.22	0.04	0	0	0	0.08	0	0
CPA-MW-1D	0	0.11	0.10	0	0.29	0.46	0	0	0	0	0.37	0.12	0.34	0	0	0	0	0	0.13	0
CPA-MW-2D	0.29	0.07	0.16	0.11	0.35	0.66	0	0.47	0.61	0.13	0.17	0.07	0	0	0	0	0	0	0.05	0
CPA-MW-3D	0.07	0.19	0.16	0.06	0.18	0.10	0	0.46	0.32	0.02	0.09	0.19	0	0	0	0	0	0	0	-
CPA-MW-4D	0.32	0.05	0.13	0.24	0.14	0.33	0	0.31	0.23	0.16	0.14	0	0	0	0	0	0	0	0	0
CPA-MW-5D	0.37	0.17	0.13	0	0.19	0.53	0	0.30	0.03	0.24	0	0	0	0	0	0	0	0	0	0
Site-Wide Average of Decreased Permeability:	**1.9E-01**																			
Mann-Kendall Trend (see Note 2):	**Decreasing**																			

Table 4a.
Summary of Phospholid Fatty Acids (PLFA) Data Analysis

Monitoring Location	Sampling Quarter 3Q08	4Q08	1Q09	2Q09	3Q09	4Q09	1Q10	4Q10	4Q10	1Q11	2Q11	3Q11	4Q11	1Q12	2Q12	3Q12	4Q12	1Q13	2Q13	3Q13
Slowed Growth (ratio cy/cis)																				
BSA-MW-1S	0.08	0.28	0.37	0.44	0.13	0.01	0	0.12	0	0.20	0	0.15	-	0.15	0.12	0.19	1.67	0.29	2.10	1.60
BSA-MW-2D	0.17	0.13	0.03	0.11	0.20	1.90	0	0.13	0.12	0	0.05	0.15	0.17	0.14	0.13	0.25	0.84	0.15	0.22	-
BSA-MW-3D	0.50	0.46	0.43	0.33	1.00	1.88	0	0.26	0.17	0	0.05	0.16	0.13	0.10	0	0	0.25	0.25	0	0.34
BSA-MW-4D	0.09	0.29	0.20	0.00	0.03	1.50	0	0.15	0.11	0.02	0	0	0.29	0.22	0	0	0	0.36	0	1.35
BSA-MW-5D	0.18	0.13	0.09	0.17	0.06	1.02	0	0.08	0.15	0.02	0.41	0.07	0	0.08	0	0	0	0.12	0.35	1.53
CPA-MW-1D	0	0.07	0.20	0.50	1.29	0.75	0	0	0	0	0	0.35	0	0.19	0	0	0.83	0.50	1.14	0.69
CPA-MW-2D	0.12	0.27	0.11	0.31	0.12	0.61	0	0	0.08	0.11	0.04	0.22	0	0.34	0	0	0	0.21	0.26	1.36
CPA-MW-3D	0.56	0.35	0.47	0.30	0.11	0.62	0	0	0.17	0.02	0.06	0.05	0	0.21	0	0	0.42	0.41	0.32	-
CPA-MW-4D	0.02	0.27	0.18	1.14	0.11	1.13	0	0	0.06	0.00	0	0.10	0	0.23	0	0	0	0	0.23	1.93
CPA-MW-5D	0.07	0.44	0.06	0.80	0.22	0.55	0	0	1.75	0.10	0	0.24	0	1.67	0	0	0	0	0.34	0.58
Site-Wide Average of Slowed Growth:	**2.2E-01**																			
Mann-Kendall Trend (see Note 2):	**No Trend**																			

Notes:
1. PLFA data are not specific to either benzene or chlorobenzene and therefore, all wells were averaged (see Section 4.4.2 of text for details.)
2. Mann-Kendall analysis presented in Figure 8.
3. Definitions:
   - = Not analyzed.
   % = Percent.
   3Q08, etc. = Third quarter 2008, etc.
   cy/cis = Cyclopropyl / cis fatty acids.
   trans/cis = Trans fatty acids / cis fatty acids.

Table 4b.
Summary of Phospholid Fatty Acids - Stable Isotope Probing (PLFA-SIP) Data Analysis

Sampling Quarter	Total Biomass (cells/bead)		Average PLFA Del (‰)		Percent Biomass Loss (%)		First Order Degradation Rate (1/day)		Degradation Half-Life (day)		DIC Del (‰)	
	BSA-MW-2D	CPA-MW-3D	BSA-MW-2D	CPA-MW-3D	BSA-MW-2D	CPA-MW-3D	BSA-MW-2D	CPA-MW-3D	BSA-MW-2D	CPA-MW-3D	BSA-MW-2D	CPA-MW-3D
3Q08	2.7E+05	9.1E+04	n/a	n/a	40	63	0.017	0.033	40.8	21.0	2917.35	0
4Q08	1.3E+05	3.2E+05	8204	0	0	60	0	0.03	0	23.1	12672	44
1Q09	8.1E+04	3.7E+05	2330	47	11	62	0.004	0.032	173.3	21.7	7683	0
2Q09	1.7E+05	2.1E+05	434	0	3	38	0.001	0.012	693.1	57.8	9444	9231
3Q09	6.9E+04	6.2E+05	49	0	1	68	0	0.032	0	21.7	0	0
4Q09	3.0E+04	1.5E+05	1191	0	0	40	0	0.017	0	40.8	7093	0
1Q10	3.3E+04	6.3E+04	2622	13	0	34	0	0.013	0	53.3	8698	36
2Q10	8.4E+04	1.7E+05	2395	0	0	0	0	0	0	0	11332	133
4Q10	1.6E+06	9.2E+05	7870	175	0	2	0	0.001	0	693.1	6827	75
4Q10	1.9E+05	3.6E+05	92	45	20	0	0.008	0	86.6	0	250	62
1Q11	3.8E+05	5.4E+05	1128	46	0	0	0	0	0	0	11874	259
2Q11	3.6E+05	7.5E+04	3753	65	0	23	0	0.009	0	77.0	28	0
3Q11	4.1E+05	4.0E+05	674	123	38	35	0.016	0.014	43.3	49.5	0	0
4Q11	1.3E+05	3.3E+04	1649	3	28	20	0.01	0.007	69.3	99.0	202	0
1Q12	4.2E+05	5.9E+04	509	6	76	0	0.046	0	15.1	0	116	0
2Q12	1.1E+05	2.4E+04	488	55	17	4	0.006	0.001	115.5	693.1	2745	31
3Q12	4.2E+04	1.4E+04	412	71	50	2	0.022	0.001	31.5	693.1	5038	0
4Q12	7.1E+04	2.4E+04	1987	38	12	3	0.004	0.001	173.3	693.1	2057	0
1Q13	1.0E+05	3.3E+04	845	0	9	20	0.003	0.007	231.0	99.0	17	0
2Q13	2.0E+04	1.1E+05	3126	87	34	4	0.013	0.001	53.3	693.1	5912	3
3Q13	3.5E+04	4.3E+04	2364	61	41	0	0.017	0	40.8	0	8	1
Temporal Average:	**2.3E+05**	**2.2E+05**	**2106**	**42**	**18**	**23**	**0.008**	**0.010**	**84**	**192**	**4520**	**470**

Notes:
‰ = Per mil.
% = Percent.
3Q08, etc. = Third quarter 2008, etc.
DIC = Direct Inorganic Carbon.
n/a = Data not reported by laboratory.
PLFA = Phospholipid Fatty Acid.

2014 PERIODIC TECHNICAL REVIEW
OF LONG-TERM MONITORING PROGRAM

Solutia Inc.
W.G. Krummrich Facility
Sauget, Illinois

Figures

Figure 1 Site Map - Long-Term Monitoring Wells

Figure 2 Representative Geologic Cross Section

Figure 3 Dissolved Phase Benzene Concentrations in DHU 2006 and 2013

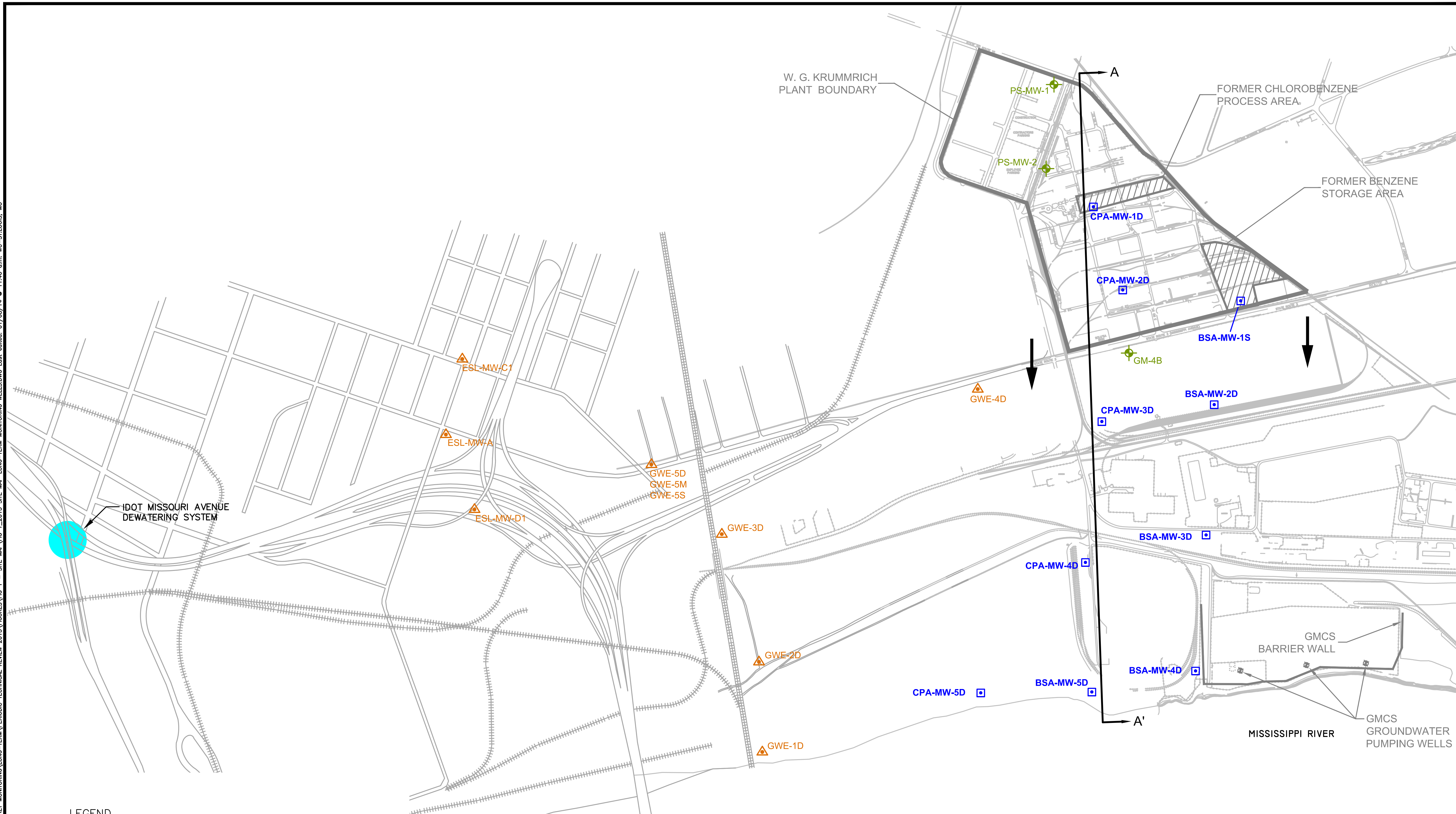
Figure 4 Dissolved Phase Chlorobenzene Concentrations in DHU 2006 and 2013

Figure 5 Temporal Trend of Dissolved Phase Benzene in DHU

Figure 6 Temporal Trend of Dissolved Phase Chlorobenzene in DHU

Figure 7 Geochemical Conditions in DHU 3rd Quarter 2008 and 2013

Figure 8 Mann-Kendall Analysis of PLFA Data



LEGEND

- LONG–TERM MONITORING WELL
- SUPPLEMENTAL MONITORING WELL
- OTHER MONITORING WELL USED IN FIGURE 2 CROSS SECTION
- GENERAL DIRECTION OF GROUNDWATER FLOW (DURING NORMAL & LOW RIVER ELEVATION)

NOTE:
SEE FIGURE 2 FOR CROSS–SECTION A–A'.

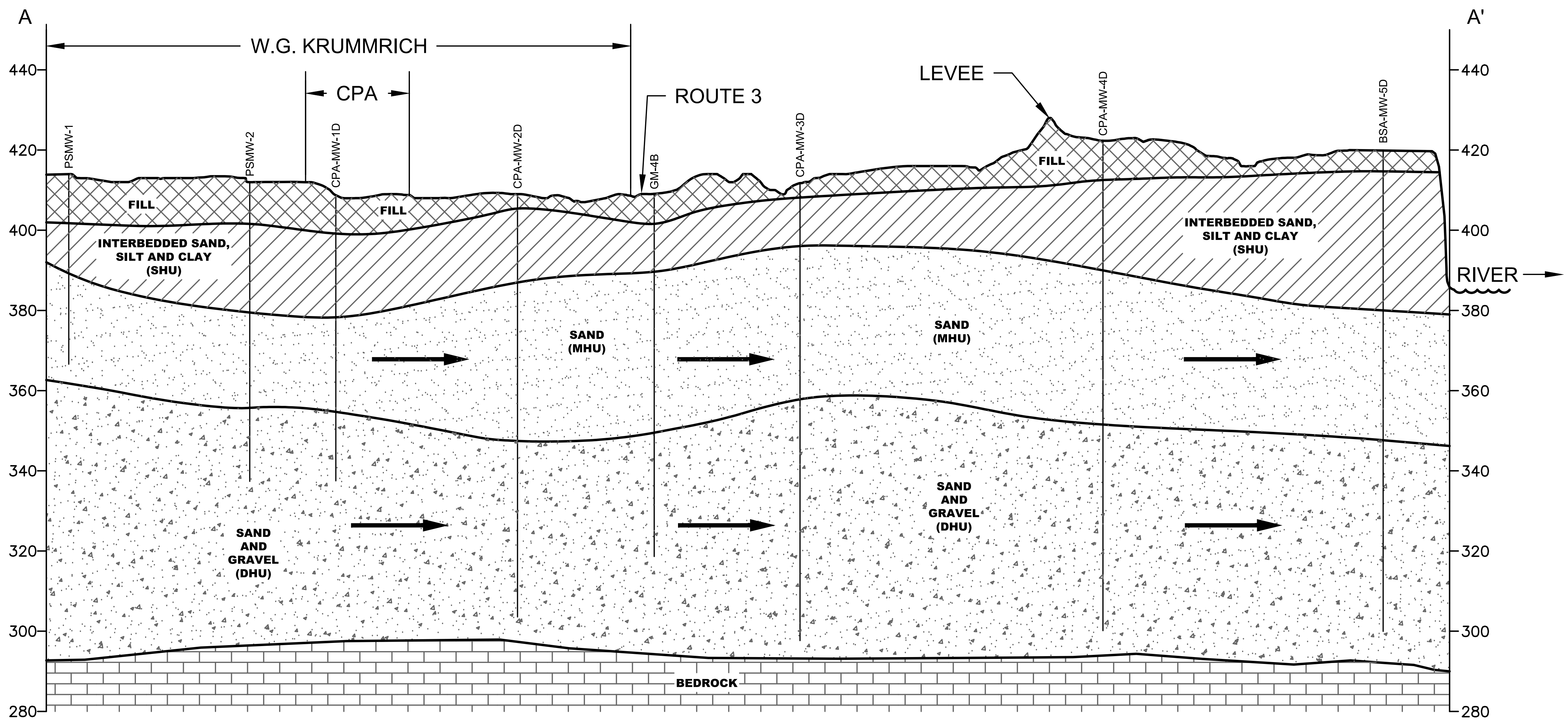
N

0 1000

SCALE FEET

2014 PERIODIC TECHNICAL REVIEW OF LONG TERM MONITORING PROGRAM SOLUTIA INC. W.G. KRUMMRICH FACILITY SAUGET, ILLINOIS	PROJECT NO. 21562941
URS	
DRN. BY:djd January 2014 DSGN. BY:nm CHKD. BY: bbb — Site Map Long–Term Monitoring Wells	FIG. NO. 1

File: P:\ENVIRONMENTAL\SOLUTIA WGK\QUARTERLY MONITORING\LONG-TERM\PERIODIC TECHNICAL REVIEW 2013\FIGURES\FIG 1 - SITE MAP\FIG 1_2013 SITE MAP LONG-TERM MONITORING WELLS.DWG Last edited: 01/08/14 @ 11:40 a.m. WC-ST.LOUIS, MO



LEGEND

GENERAL DIRECTION OF GROUNDWATER FLOW (DURING NORMAL & LOW RIVER ELEVATION)

FILL

INTERBEDDED SAND, SILT AND CLAY (SHU)

SAND (MHU)

SAND AND GRAVEL (DHU)

BEDROCK

NOTE:
SEE FIGURE 1 FOR LOCATION OF CROSS-SECTION.

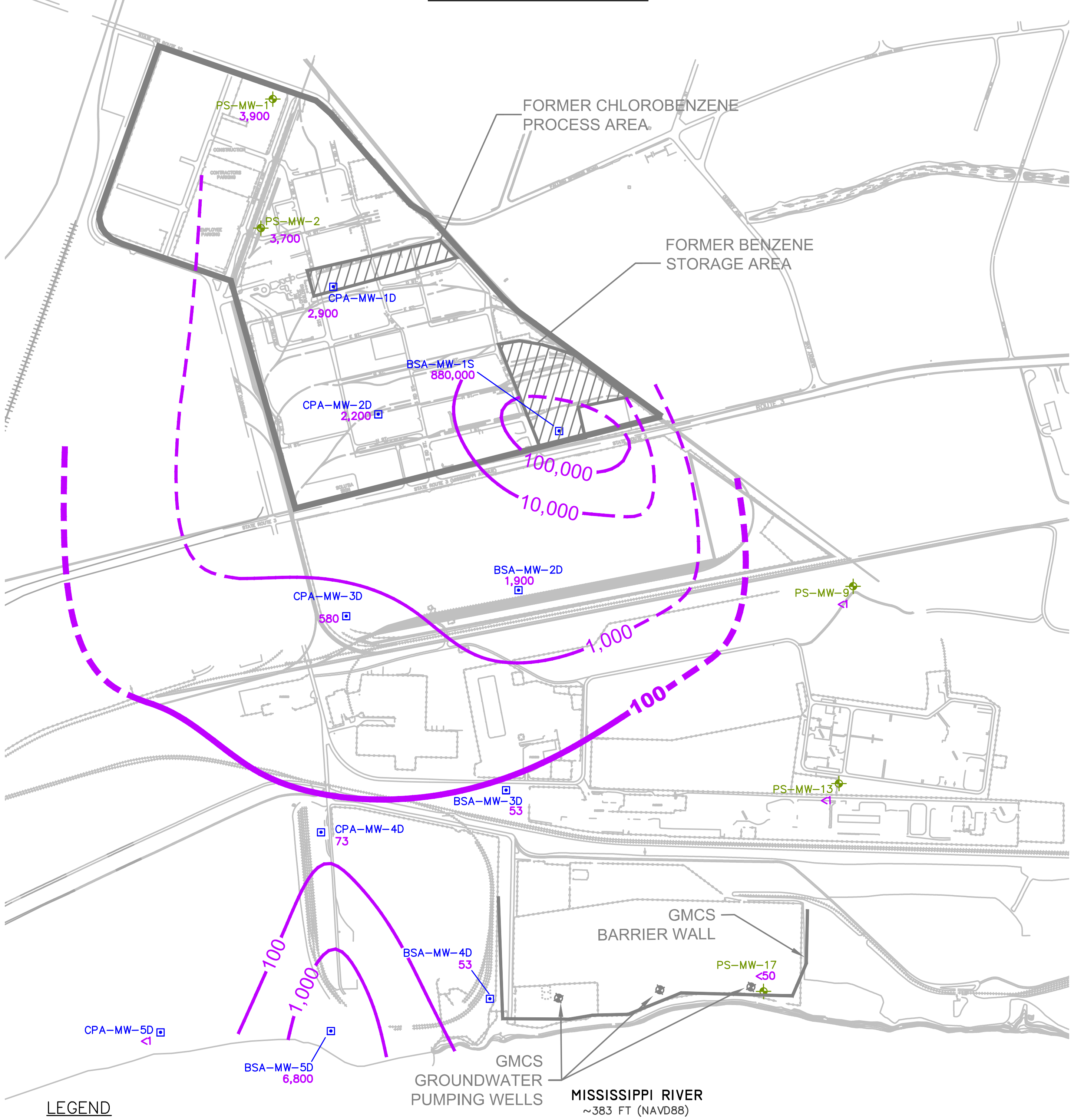
0 600
SCALE FEET
APPROXIMATE HORIZONTAL SCALE

0 30
SCALE FEET
VERTICAL SCALE

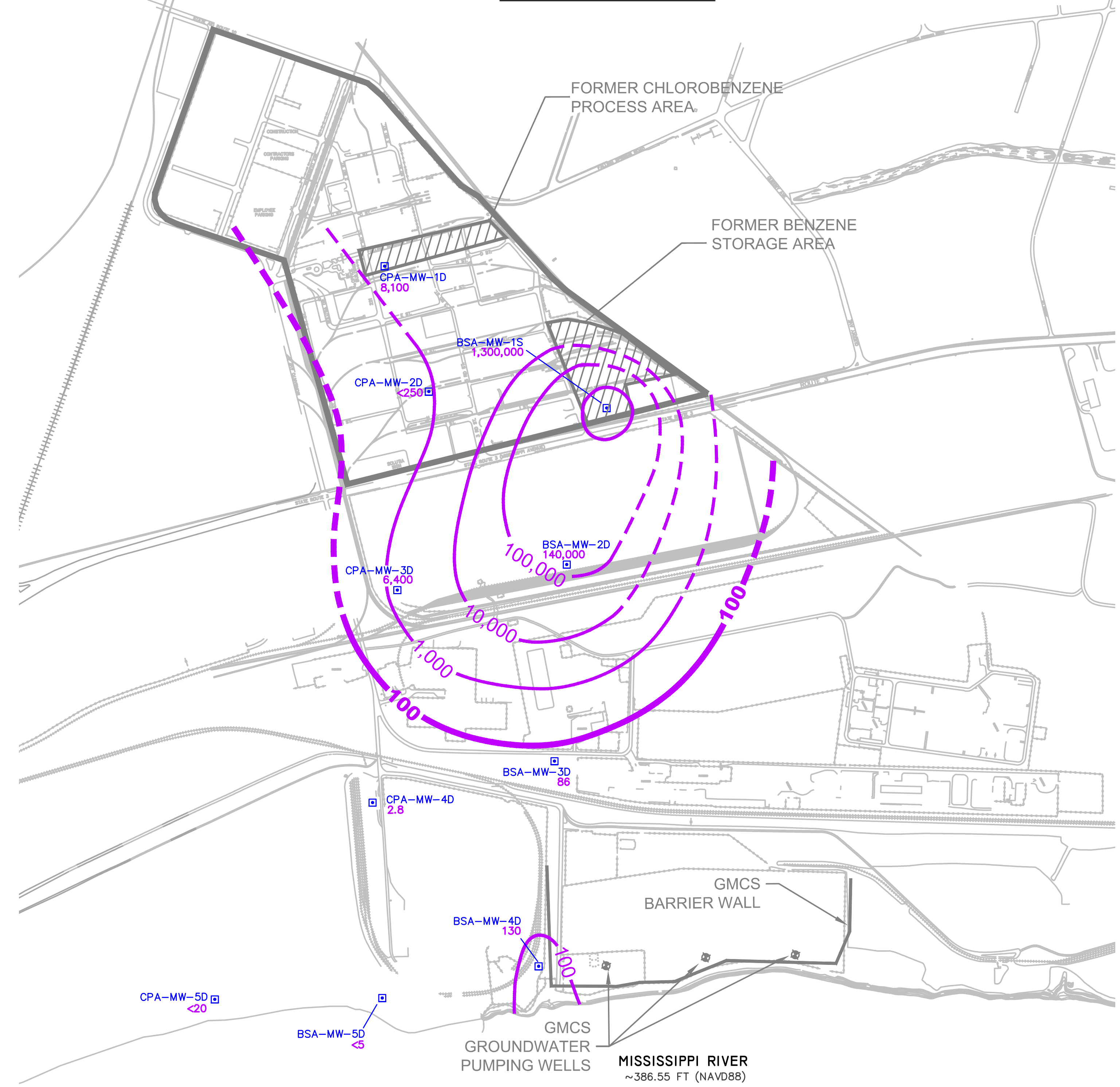
2014 PERIODIC TECHNICAL REVIEW OF LONG TERM MONITORING PROGRAM SOLUTIA INC. W.G. KRUMMRICH FACILITY SAUGET, ILLINOIS		PROJECT NO. 21562941
URS		
DRN. BY: djd January 2014 DSGN. BY: mec CHKD. BY: bbb	Representative Geologic Cross Section	FIG. NO. 2

File: P:\ENVIRONMENTAL\SOLUTIA WGK\QUARTERLY MONITORING\LONG-TERM\PERIODIC TECHNICAL REVIEW 2013\FIGURES\FIG 2 - CROSS SECTION\FIG 2_2013 REPRESENTATIVE GEOLOGIC CROSS SECTION.DWG Last edited: JAN. 08, 14 @ 11:30 a.m. by: david_deguire

2ND QUARTER 2006



3RD QUARTER 2013



LEGEND

LONG-TERM MONITORING WELL

OTHER MONITORING WELL USED FOR GROUNDWATER CONTOURING

100 ESTIMATED BENZENE CONCENTRATION CONTOUR (ug/L) IN DHU
(ISOCONCENTRATION CONTOURS DASHED WHERE INTERPRETED)

NOTE:
CONTOURS DRAWN BASED ON PROFESSIONAL JUDGEMENT.

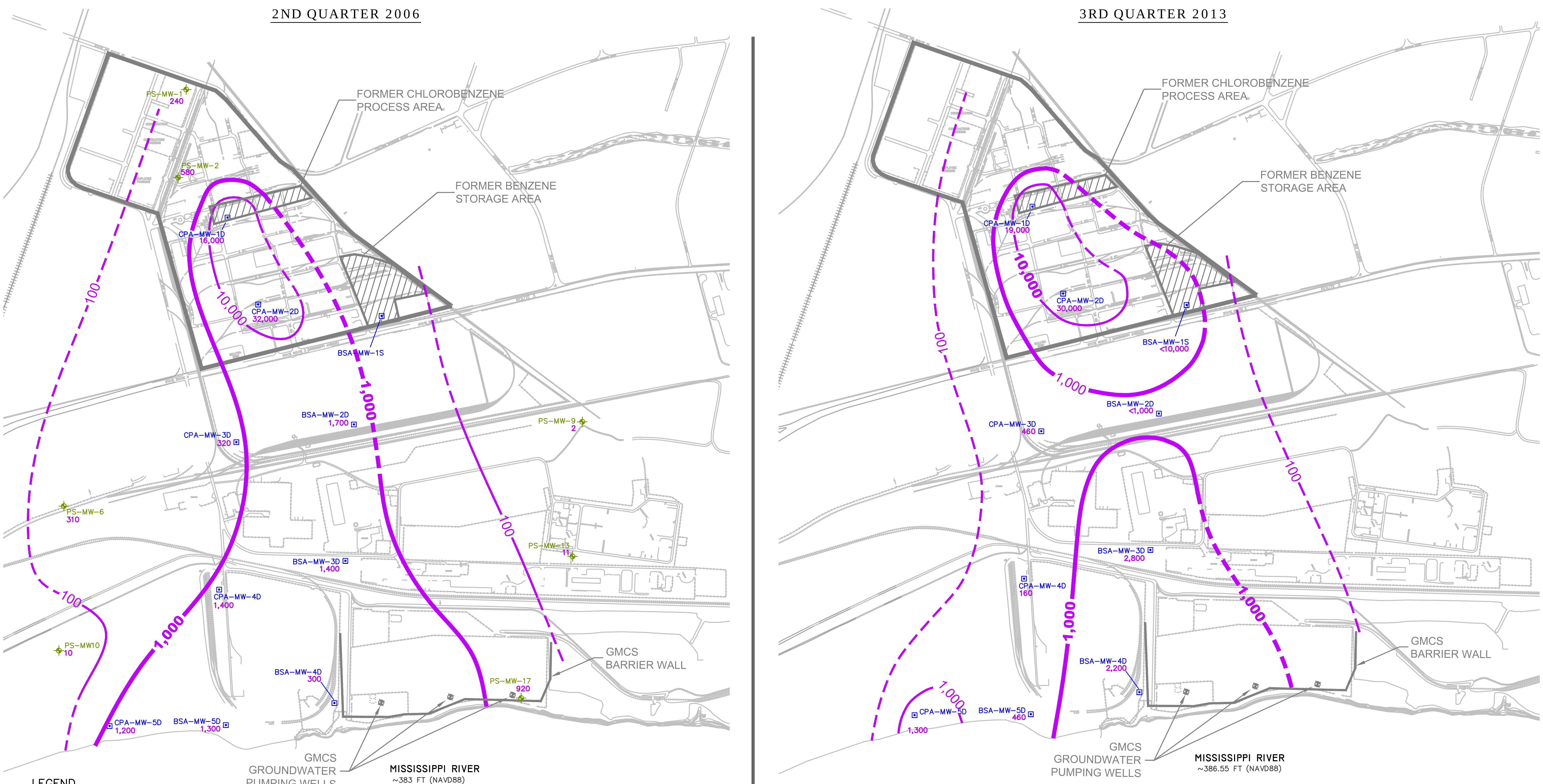
N

0 1000

SCALE FEET

2014 PERIODIC TECHNICAL REVIEW OF LONG TERM MONITORING PROGRAM SOLUTIA INC. W.G. KRUMMRICH FACILITY SAUGET, ILLINOIS		PROJECT NO. 21562941
URS		
DRN. BY:djd January 2014 DSGN. BY:nm CHKD. BY:bbb/rt	Dissolved Phase Benzene Concentrations in DHU 2006 and 2013	FIG. NO. 3

File: P:\ENVIRONMENTAL\SOLUTIA WGK\QUARTERLY MONITORING\LONG-TERM\PERIODIC TECHNICAL REVIEW 2013\FIGURES\FIG 3 - BENZENE PLUME\FIG 3_DISSOLVED PHASE BENZENE CONCENTRATIONS 2006 AND 2013.DWG Last edited: 01/08/14 @ 11:18 a.m. WC-ST.LOUIS, MO



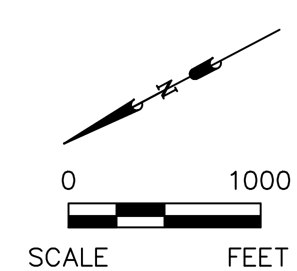
LEGEND

LONG-TERM MONITORING WELL

OTHER MONITORING WELL USED FOR GROUNDWATER CONTOURING

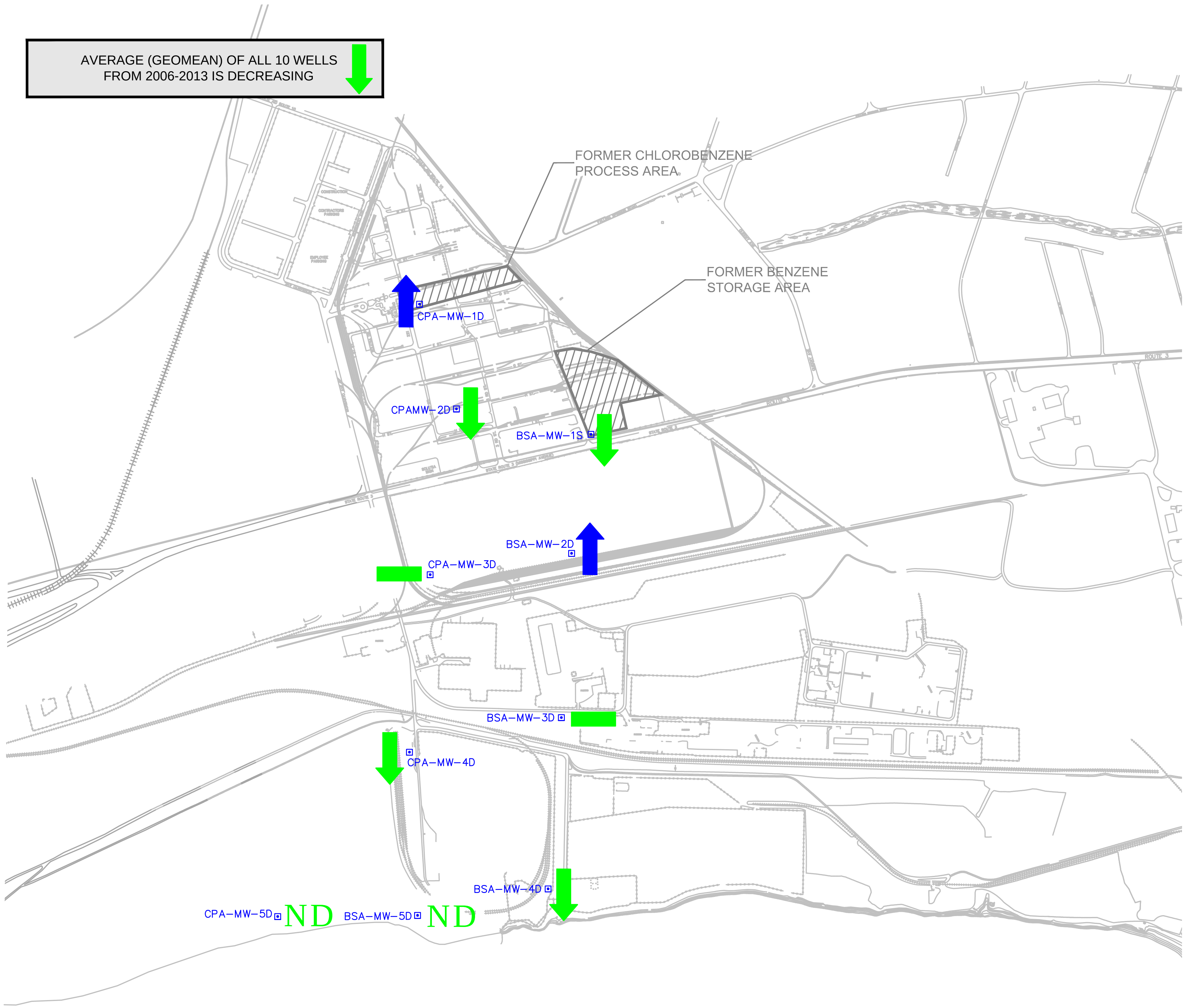
100 — ESTIMATED CHLOROBENZENE CONCENTRATION CONTOUR (ug/L) IN DHU (ISOCONCENTRATION CONTOURS DASHED WHERE INTERPRETED)

NOTE:
CONTOURS DRAWN BASED ON PROFESSIONAL JUDGEMENT.



2014 PERIODIC TECHNICAL REVIEW OF LONG TERM MONITORING PROGRAM SOLUTIA INC. W.G. KRUMMRICH FACILITY SAUGET, ILLINOIS	PROJECT NO. 21562941
URS	
DRN. BY:djd January 2014 DSGN. BY:nm CHKD. BY:bbb/rt	Dissolved Phase Chlorobenzene Concentrations in DHU 2006 and 2013 — FIG. NO. 4

File: P:\ENVIRONMENTAL\SOLUTIA WGK\QUARTERLY MONITORING\LONG-TERM\PERIODIC TECHNICAL REVIEW 2013\FIGURES\FIG 4 - MCB PLUME\FIG 4_DISSOLVED PHASE CHLOROBENZENE CONCENTRATIONS IN DHU 2006 AND 2013.DWG Last edited: 01/08/14 @ 4:15 p.m. WC-ST.LOUIS, MO



LEGEND

⊡ LONG–TERM MONITORING WELL

MANN-KENDALL CONCENTRATION TRENDS
(1Q06 - 3Q13):

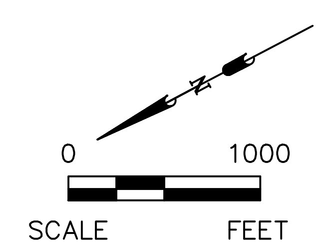
ND CONSTITUENT PREDOMINANTLY NOT DETECTED OVER TIME

STABLE OR NO TREND

DECREASING

INCREASING

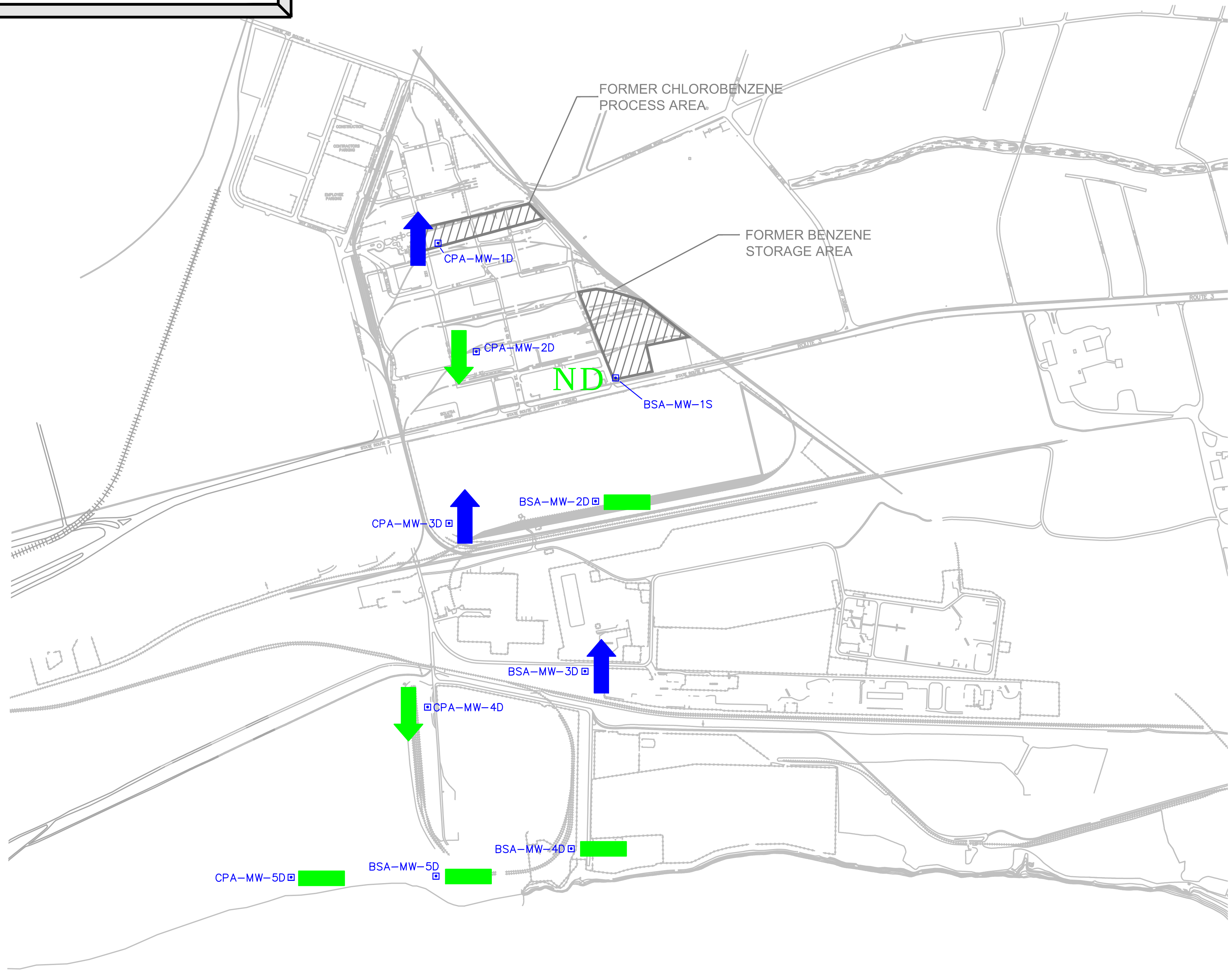
NOTES:
1. SEE TABLE 2 FOR 2006 THROUGH 2013 BENZENE CONCENTRATIONS IN GROUNDWATER.
2. SEE ATTACHMENT 1 FOR A DETAILED SUMMARY OF THE MANN–KENDALL ANALYSIS.



2014 PERIODIC TECHNICAL REVIEW OF LONG TERM MONITORING PROGRAM SOLUTIA INC. W.G. KRUMMRICH FACILITY SAUGET, ILLINOIS	PROJECT NO. 21562941
URS	
DRN. BY:djd January 2014 DSGN. BY:nm CHKD. BY: bbb/rt	Temporal Trend of Dissolved Phase Benzene in DHU
FIG. NO.	5

File: P:\ENVIRONMENTAL\SOLUTIA WGK\QUARTERLY MONITORING\LONG-TERM\PERIODIC TECHNICAL REVIEW 2013\FIGURES\FIG 5 - BENZENE TEMPORAL\FIG 5_TEMPORAL TREND OF DISSOLVED PHASE BENZENE IN DHU.DWG Last edited: 01/08/14 @ 11:55 a.m. WC-ST.LOUIS, MO

AVERAGE (GEOMEAN) OF ALL WELLS FROM 2006-2013 IS STABLE.



LEGEND

LONG-TERM MONITORING WELL

MANN-KENDALL CONCENTRATION TRENDS (1Q06 - 3Q13):

ND CONSTITUENT PREDOMINANTLY NOT DETECTED OVER TIME

STABLE OR NO TREND

DECREASING

INCREASING

NOTES:
1. SEE TABLE 2 FOR 2006 THROUGH 2013 CHLOROBENZENE CONCENTRATIONS IN GROUNDWATER.
2. SEE ATTACHMENT 1 FOR A DETAILED SUMMARY OF THE MANN-KENDALL ANALYSIS.

N

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SCALE FEET

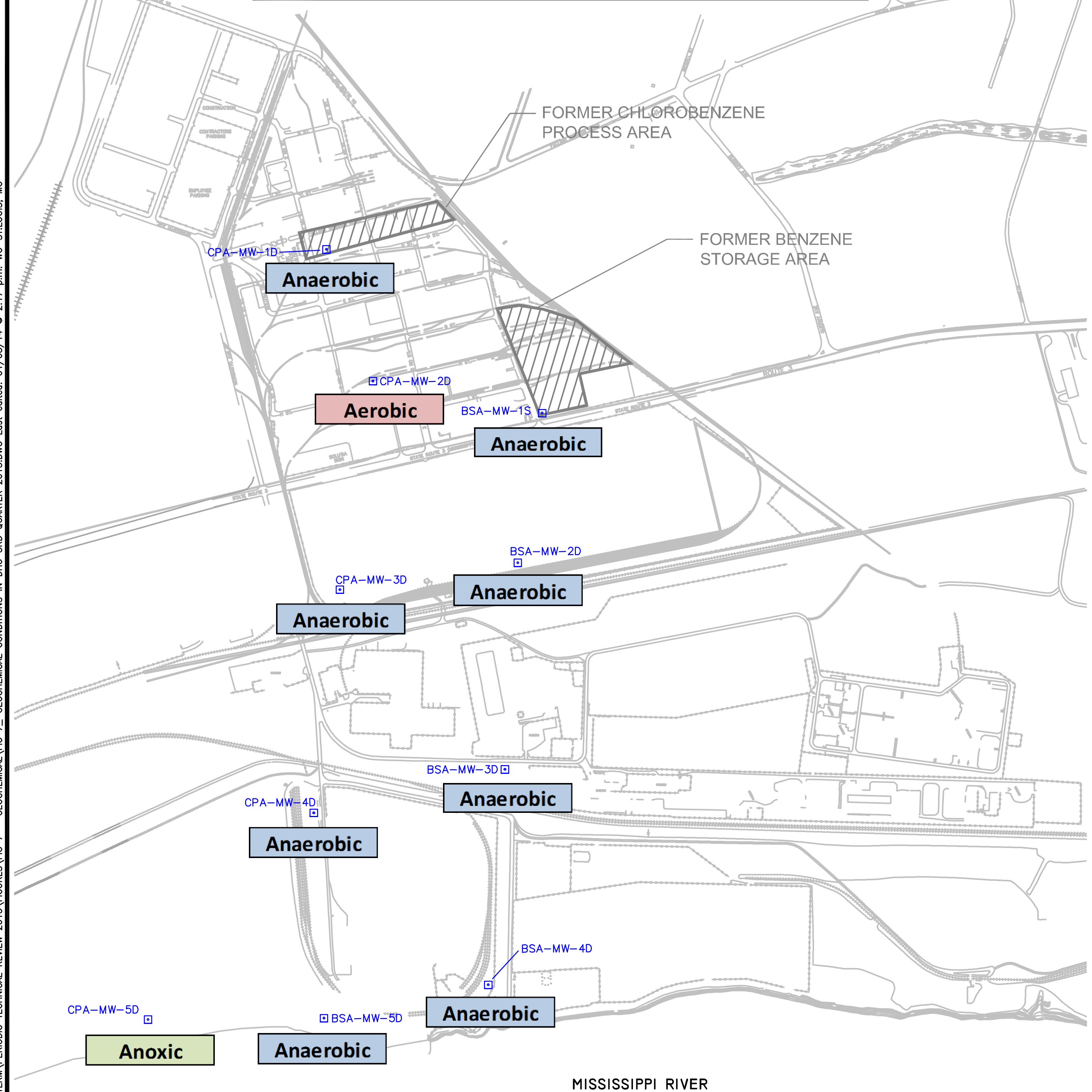
2014 PERIODIC TECHNICAL REVIEW OF LONG TERM MONITORING PROGRAM SOLUTIA INC. W.G. KRUMMRICH FACILITY SAUGET, ILLINOIS	PROJECT NO. 21562941
DRN. BY: djd January 2014 DSGN. BY: nm CHKD. BY: bbb	Temporal Trend of Dissolved Phase Chlorobenzene in DHU — FIG. NO. 6

URS

File: P:\ENVIRONMENTAL\SOLUTIA WGK\QUARTERLY MONITORING\LONG-TERM\PERIODIC TECHNICAL REVIEW 2013\FIGURES\FIG 6 - MCB TEMPORAL\FIG 6_ TEMPORAL TREND OF DISSOLVED PHASE CHLOROBENZENE IN DHU .DWG Last edited: 01/08/14 @ 12:18 p.m. WC-ST.LOUIS, MO

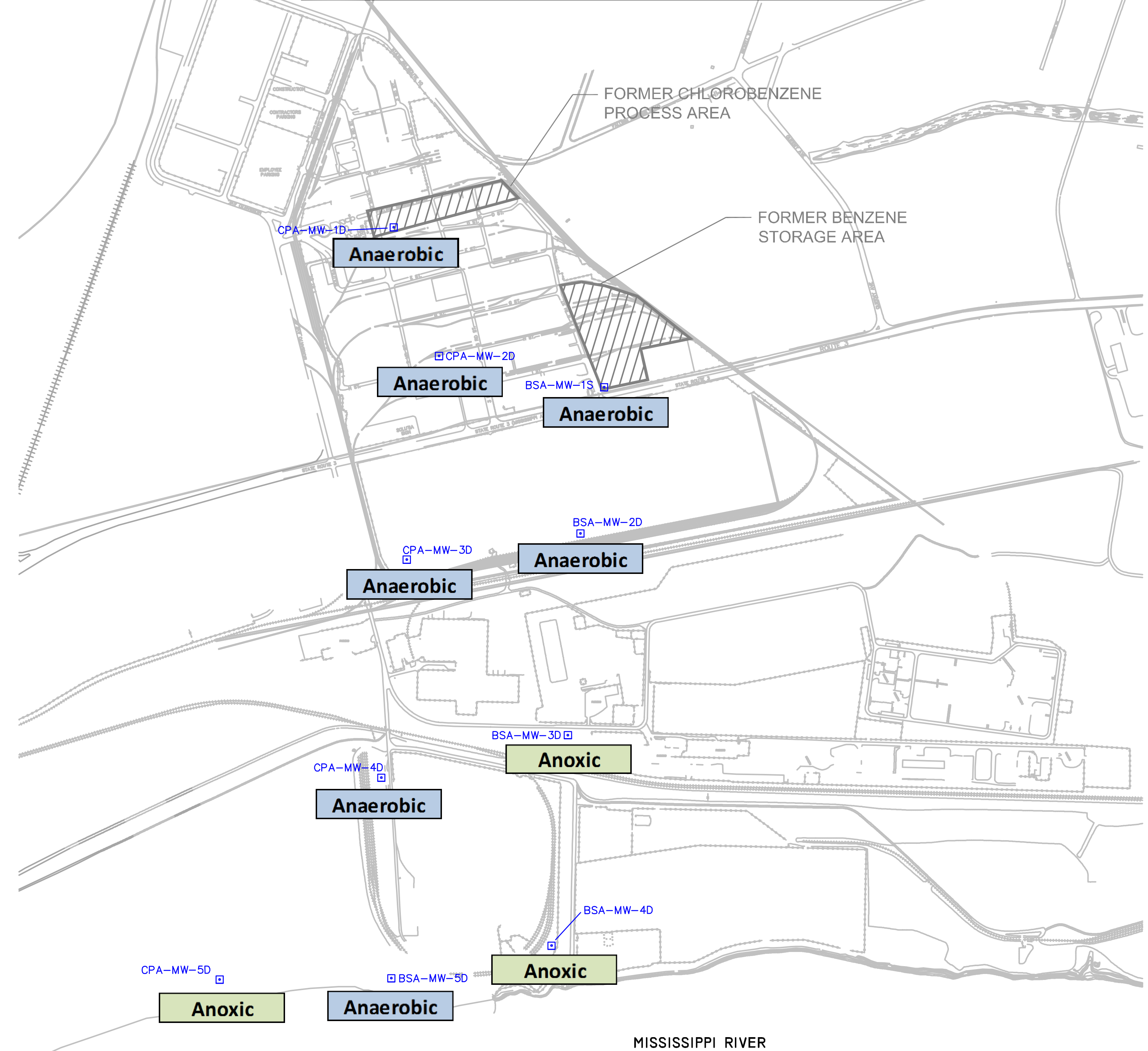
3RD QUARTER 2008

ALL TEN WELLS SUPPORT NATURAL ATTENUATION



3RD QUARTER 2013

ALL TEN WELLS SUPPORT NATURAL ATTENUATION



LEGEND

⊡ LONG-TERM MONITORING WELL

NOTE:
AEROBIC, ANAEROBIC, AND ANOXIC GROUNDWATER GEOCHEMISTRY WAS DETERMINED USUNG THE METHOD PRESENTED IN ATTACHMENT 2,

N

0 1000

SCALE FEET

2014 PERIODIC TECHNICAL REVIEW OF LONG TERM MONITORING PROGRAM SOLUTIA INC. W.G. KRUMMRICH FACILITY SAUGET, ILLINOIS	PROJECT NO. 21562941
URS	
DRN. BY:djd January 2014 DSGN. BY:nm CHKD. BY:bbb	Geochemical Conditions in DHU 3rd Quarter 2008 & 2013 — FIG. NO. 7

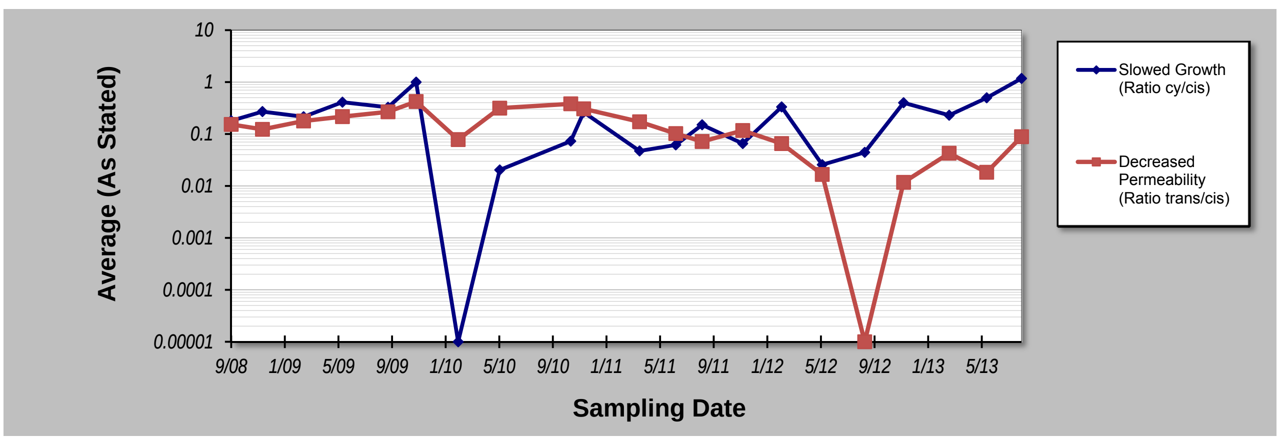
File: P:\ENVIRONMENTAL\SOLUTIA WGK\!QUARTERLY MONITORING\LONG-TERM\PERIODIC TECHNICAL REVIEW 2013\FIGURES\FIG 7 – GEOCHEMICAL\FIG 7_ GEOCHEMICAL CONDITIONS IN DHU 3RD QUARTER 2013.DWG Last edited: 01/08/14 @ 2:17 p.m. WC-ST.LOUIS, MO

Figure 8
Constituent Trend Analysis - The Mann-Kendall Test
Phospholipid Fatty Acids

GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date: **19-Nov-13**
Facility Name: **W.G. Krummrich**
Constituent: **Site Wide Averages**
Concentration Units: **As Stated**

Sampling Point ID:		Slowed Growth (Ratio cy/cis)	Decreased Permeability (Ratio trans/cis)					
Sampling Event	Sampling Date	SITE WIDE AVERAGES (As Stated)						
1	Sep-08	0.2	0.2					
2	Dec-08	0.3	0.1					
3	Mar-09	0.2	0.2					
4	Jun-09	0.4	0.2					
5	Sep-09	0.3	0.3					
6	Nov-09	1.0	0.4					
7	Feb-10	0.0	0.1					
8	May-10	0.02	0.3					
9	Oct-10	0.1	0.4					
10	Nov-10	0.3	0.3					
11	Mar-11	0.05	0.2					
12	Jun-11	0.1	0.1					
13	Aug-11	0.2	0.1					
14	Nov-11	0.1	0.1					
15	Feb-12	0.3	0.1					
16	May-12	0.03	0.02					
17	Aug-12	0.04	0.0					
18	Nov-12	0.4	0.01					
19	Feb-13	0.2	0.04					
20	May-13	0.5	0.02					
21	Jul-13	1.2	0.1					
22								
23								
24								
25								
Coefficient of Variation:		1.12	0.84					
Mann-Kendall Statistic (S):		22	-100					
Confidence Factor:		73.5%	99.9%					
Concentration Trend:		No Trend	Decreasing					



Notes:

1. At least four independent sampling events per well are required for calculating the trend. *Methodology is valid for 4 to 40 samples.*
2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C.J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.

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January 2014

2014 PERIODIC TECHNICAL REVIEW
OF LONG-TERM MONITORING PROGRAM
Solutia Inc.
W.G. Krummrich Facility
Sauget, Illinois

Attachments

Attachment 1	Constituent Trend Analysis – The Mann Kendall Test
Attachment 2	Truex et al., 2006: Geochemical Conditions (Select Pages)
Attachment 3	Northern Plume Stability Analysis

2014 PERIODIC TECHNICAL REVIEW
OF LONG-TERM MONITORING PROGRAM

Solutia Inc.
W.G. Krummrich Facility
Sauget, Illinois

Attachments

Attachment 1

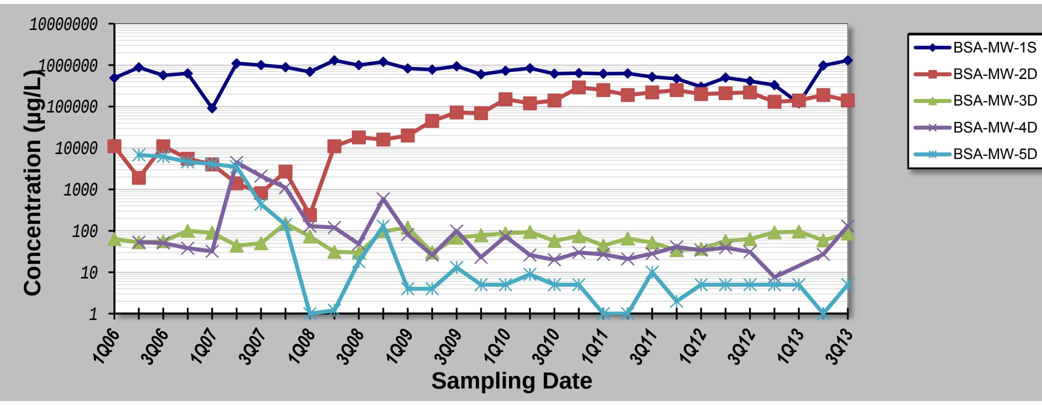
Constituent Trend Analysis – The Mann Kendall Test

Attachment 1
Constituent Trend Analysis - The Mann-Kendall Test
Benzene Storage Area Monitoring Wells
Benzene

GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	November 2013	Job ID:	21562941
Facility Name:	W.G. Krummrich Plant, Sauget, IL	Constituent:	Benzene
Conducted By:	Nathan McNurlen - URS Corporation	Concentration Units:	µg/L

		Sampling Point ID:						
		BSA-MW-1S	BSA-MW-2D	BSA-MW-3D	BSA-MW-4D	BSA-MW-5D		
Sampling Event	Sampling Date	BENZENE CONCENTRATION (µg/L)						
1	1Q06	490000	11000	63				
2	2Q06	880000	1900	53	53	6800		
3	3Q06	570000	11000	56	51	6200		
4	4Q06	630000	5500	100	38	4600		
5	1Q07	91000	4000	90	32	4100		
6	2Q07	1100000	1400	44	4500	3500		
7	3Q07	1000000	810	50	2100	440		
8	4Q07	890000	2700	150	1100	140		
9	1Q08	690000	240	73	130	1		
10	2Q08	1300000	11000	31	120	1.2		
11	3Q08	1000000	18000	30	48	18		
12	4Q08	1200000	16000	97	590	130		
13	1Q09	830000	20000	120	82	4		
14	2Q09	780000	45000	30	26	4		
15	3Q09	940000	72000	68	99	13		
16	4Q09	600000	69000	78	23	5		
17	1Q10	730000	150000	87	73	5		
18	2Q10	840000	120000	94	26	8.9		
19	3Q10	620000	140000	57	20	5		
20	4Q10	640000	290000	75	30	5		
21	1Q11	620000	250000	44	27	1		
22	2Q11	630000	190000	65	21	1		
23	3Q11	520000	220000	52	28	10		
24	4Q11	470000	250000	34	41	2		
25	1Q12	300000	200000	37	34	5		
26	2Q12	500000	210000	57	39	5		
27	3Q12	410000	220000	63	31	5		
28	4Q12	330000	130000	92	7.6	5		
29	1Q13	120000	140000	96		5		
30	2Q13	980000	190000	59	27	1		
31	3Q13	1300000	140000	86	130	5		
32								
33								
34								
35								
Coefficient of Variation:		0.44	0.94	0.41	2.77	2.27		
Mann-Kendall Statistic (S):		-117	284	-1	-141	-195		
Confidence Factor:		97.6%	>99.9%	50.0%	99.6%	>99.9%		
Concentration Trend:		Decreasing	Increasing	Stable	Decreasing	Decreasing		



Notes:

1. At least four independent sampling events per well are required for calculating the trend. *Methodology is valid for 4 to 40 samples.*
2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C.J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.
4. Grey results indicate that the analyte was not detected above the reporting limit shown.

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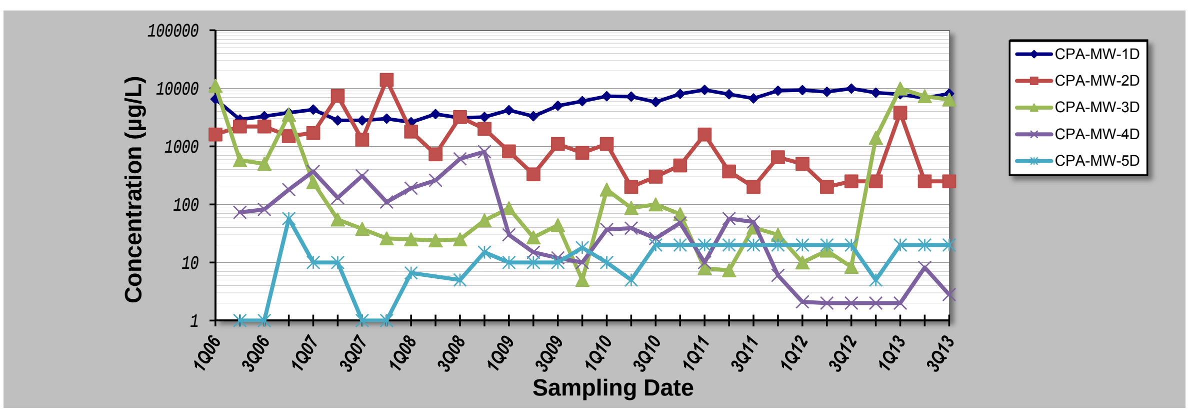
Attachment 1
Constituent Trend Analysis - The Mann-Kendall Test
Chlorobenzene Process Area Monitoring Wells
Benzene

GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	November 2013	Job ID:	21562941
Facility Name:	W.G. Krummrich Plant, Sauget, IL	Constituent:	Benzene
Conducted By:	Nathan McNurlen - URS Corporation	Concentration Units:	µg/L

Sampling Event	Sampling Date	CPA-MW-1D	CPA-MW-2D	CPA-MW-3D	CPA-MW-4D	CPA-MW-5D
		BENZENE CONCENTRATION (µg/L)				
1	1Q06	6500	1600	11000		
2	2Q06	2900	2200	580	73	1
3	3Q06	3300	2200	500	82	1
4	4Q06	3800	1500	3500	180	57
5	1Q07	4300	1700	240	370	10
6	2Q07	2800	7400	55	130	10
7	3Q07	2800	1300	38	310	1
8	4Q07	3000	14000	26	110	1
9	1Q08	2600	1800	25	190	6.6
10	2Q08	3600	730	24	260	
11	3Q08	3100	3200	25	610	5
12	4Q08	3200	2000	53	810	15
13	1Q09	4200	820	86	30	10
14	2Q09	3300	330	27	15	10
15	3Q09	5000	1100	44	12	10
16	4Q09	6000	770	5	10	18
17	1Q10	7300	1100	180	37	10
18	2Q10	7200	200	87	39	5
19	3Q10	5800	300	100	26	20
20	4Q10	8000	470	68	48	20
21	1Q11	9400	1600	8	10	20
22	2Q11	7900	370	7.3	57	20
23	3Q11	6700	200	40	50	20
24	4Q11	9100	650	30	6	20
25	1Q12	9300	500	10	2.1	20
26	2Q12	8700	200	16	2	20
27	3Q12	9900	250	8.4	2	20
28	4Q12	8400	250	1400	2	5
29	1Q13	7900	3800	9900	2	20
30	2Q13	6800	250	7300	8.2	20
31	3Q13	8100	250	6400	2.8	20
32						
33						
34						
35						
Coefficient of Variation:		0.42	1.58	2.23	1.63	0.76
Mann-Kendall Statistic (S):		274	-229	-56	-244	182
Confidence Factor:		>99.9%	>99.9%	82.4%	>99.9%	>99.9%
Concentration Trend:		Increasing	Decreasing	No Trend	Decreasing	Increasing



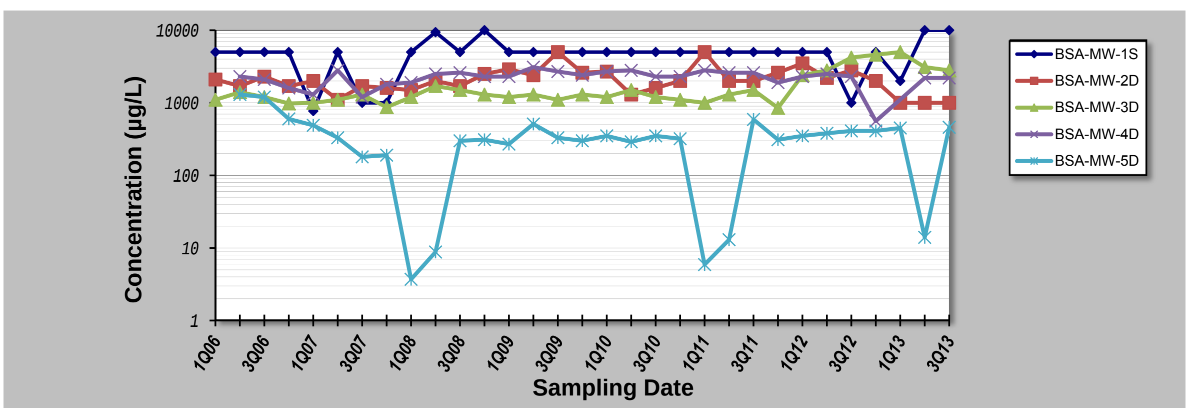
Notes:
1. At least four independent sampling events per well are required for calculating the trend. *Methodology is valid for 4 to 40 samples.*
2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C.J. Newell, and J.R. Gonzales, *Ground Water* , 41(3):355-367, 2003.
4. Grey results indicate that the analyte was not detected above the reporting limit shown.

GSI Environmental Inc., www.gsi-net.com

GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date: November 2013
Facility Name: W.G. Krummrich Plant, Sauget, IL
Conducted By: Nathan McNurlen - URS Corporation
Job ID: 21562941
Constituent: Chlorobenzene
Concentration Units: µg/L

Sampling Point ID:		BSA-MW-1S	BSA-MW-2D	BSA-MW-3D	BSA-MW-4D	BSA-MW-5D		
Sampling Event	Sampling Date	CHLOROBENZENE CONCENTRATION (µg/L)						
1	1Q06	5000	2100	1100				
2	2Q06	5000	1700	1400	2300	1300		
3	3Q06	5000	2300	1200	2100	1200		
4	4Q06	5000	1700	980	1600	600		
5	1Q07	770	2000	1000	1300	490		
6	2Q07	5000	1100	1100	2800	330		
7	3Q07	1000	1700	1300	1200	180		
8	4Q07	1000	1600	870	1800	190		
9	1Q08	5000	1500	1200	1900	3.7		
10	2Q08	9400	2000	1700	2500	8.8		
11	3Q08	5000	1700	1500	2600	300		
12	4Q08	10000	2500	1300	2300	310		
13	1Q09	5000	2900	1200	2300	270		
14	2Q09	5000	2400	1300	3100	510		
15	3Q09	5000	5000	1100	2700	330		
16	4Q09	5000	2600	1300	2400	300		
17	1Q10	5000	2700	1200	2700	350		
18	2Q10	5000	1300	1500	2800	290		
19	3Q10	5000	1600	1200	2300	350		
20	4Q10	5000	2000	1100	2300	320		
21	1Q11	5000	5000	1000	2800	5.9		
22	2Q11	5000	2000	1300	2600	13		
23	3Q11	5000	2000	1500	2600	590		
24	4Q11	5000	2600	850	1900	310		
25	1Q12	5000	3500	2400	2300	350		
26	2Q12	5000	2200	2800	2500	380		
27	3Q12	1000	2800	4200	2300	410		
28	4Q12	5000	2000	4600	560	410		
29	1Q13	2000	1000	5000		450		
30	2Q13	10000	1000	3100	2200	14		
31	3Q13	10000	1000	2800	2200	460		
32								
33								
34								
35								
Coefficient of Variation:		0.47	0.44	0.64	0.24	0.79		
Mann-Kendall Statistic (S):		44	16	186	21	16		
Confidence Factor:		76.6%	60.0%	99.9%	64.5%	60.5%		
Concentration Trend:		No Trend	No Trend	Increasing	No Trend	No Trend		



Notes:

1. At least four independent sampling events per well are required for calculating the trend. *Methodology is valid for 4 to 40 samples.*
2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C.J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.
4. Grey results indicate that the analyte was not detected above the reporting limit shown.

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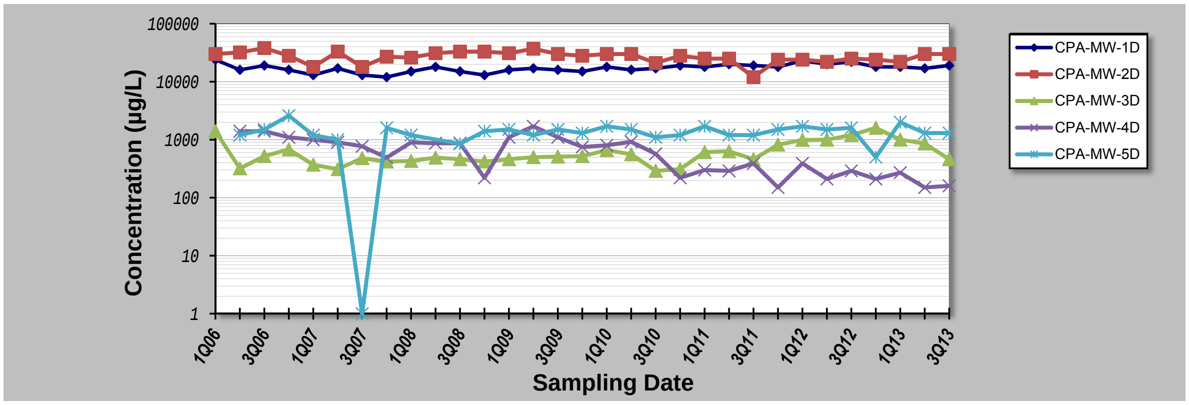
Attachment 1
Constituent Trend Analysis - The Mann-Kendall Test
Chlorobenzene Process Area Monitoring Wells
Chlorobenzene

GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date: November 2013 | Job ID: 21562941
Facility Name: W.G. Krummrich Plant, Sauget, IL | Constituent: Chlorobenzene
Conducted By: Nathan McNurlen - URS Corporation | Concentration Units: μg/L

Sampling Event	Sampling Date	CPA-MW-1D	CPA-MW-2D	CPA-MW-3D	CPA-MW-4D	CPA-MW-5D		
		CHLOROBENZENE CONCENTRATION (μg/L)						
1	1Q06	24000	30000	1400				
2	2Q06	16000	32000	320	1400	1200		
3	3Q06	19000	38000	520	1400	1500		
4	4Q06	16000	28000	680	1100	2600		
5	1Q07	13000	18000	370	1000	1200		
6	2Q07	17000	33000	310	900	1000		
7	3Q07	13000	18000	480	770	1		
8	4Q07	12000	27000	420	490	1600		
9	1Q08	15000	26000	430	900	1200		
10	2Q08	18000	31000	490	870			
11	3Q08	15000	33000	460	870	850		
12	4Q08	13000	33000	420	220	1400		
13	1Q09	16000	31000	460	1100	1500		
14	2Q09	17000	37000	500	1700	1200		
15	3Q09	16000	30000	510	1100	1500		
16	4Q09	15000	28000	520	750	1300		
17	1Q10	18000	30000	660	800	1700		
18	2Q10	16000	30000	560	920	1500		
19	3Q10	17000	21000	290	570	1100		
20	4Q10	19000	28000	310	220	1200		
21	1Q11	18000	25000	610	300	1700		
22	2Q11	20000	25000	630	290	1200		
23	3Q11	19000	12000	460	390	1200		
24	4Q11	18000	24000	820	150	1500		
25	1Q12	23000	24000	990	390	1700		
26	2Q12	20000	22000	1000	210	1500		
27	3Q12	22000	25000	1200	290	1600		
28	4Q12	18000	24000	1600	210	500		
29	1Q13	18000	22000	1000	270	2000		
30	2Q13	17000	30000	860	150	1300		
31	3Q13	19000	30000	460	160	1300		
32								
33								
34								
35								
Coefficient of Variation:		0.16	0.21	0.51	0.66	0.34		
Mann-Kendall Statistic (S):		165	-141	175	-270	55		
Confidence Factor:		99.8%	99.2%	99.9%	>99.9%	84.3%		
Concentration Trend:		Increasing	Decreasing	Increasing	Decreasing	No Trend		



Notes:

1. At least four independent sampling events per well are required for calculating the trend. *Methodology is valid for 4 to 40 samples.*
2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C.J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.
4. Grey results indicate that the analyte was not detected above the reporting limit shown.

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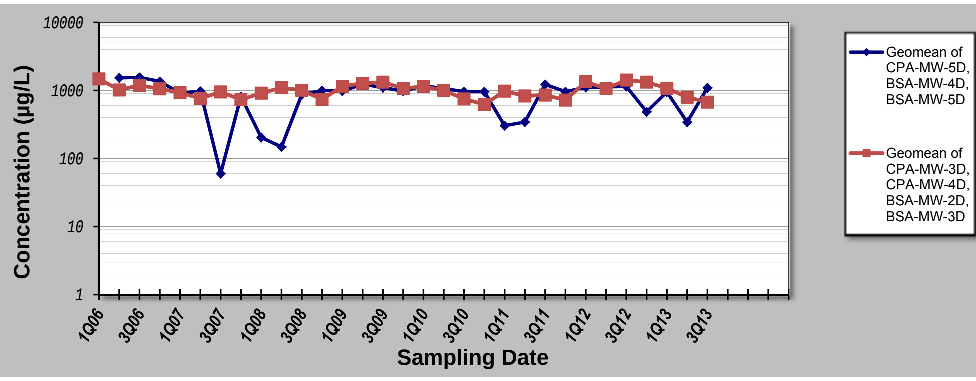
Attachment 1
Constituent Trend Analysis - The Mann-Kendall Test
Benzene Storage Area and Chlorobenzene Process Area Monitoring Wells
Chlorobenzene Geomeans

GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date: **November 2013**
Facility Name: **W.G. Krummrich Plant, Sauget, IL**
Conducted By: **Nathan McNurlen - URS Corporation**
Job ID: **21562941**
Constituent: **Chlorobenzene**
Concentration Units: **µg/L**

Sampling Event	Sampling Date	Geomean of CPA-MW-5D, BSA-MW-4D, BSA-MW-5D	Geomean of CPA-MW-3D, CPA-MW-4D, BSA-MW-2D, BSA-MW-3D					
		CHLOROBENZENE CONCENTRATION (µg/L)						
1	1Q06		1479					
2	2Q06	1531	1016					
3	3Q06	1558	1191					
4	4Q06	1356	1057					
5	1Q07	914	927					
6	2Q07	974	762					
7	3Q07	60	951					
8	4Q07	818	732					
9	1Q08	204	914					
10	2Q08	148	1097					
11	3Q08	872	1005					
12	4Q08	999	740					
13	1Q09	977	1152					
14	2Q09	1238	1276					
15	3Q09	1102	1325					
16	4Q09	978	1072					
17	1Q10	1171	1144					
18	2Q10	1068	1001					
19	3Q10	960	751					
20	4Q10	959	622					
21	1Q11	304	978					
22	2Q11	344	830					
23	3Q11	1226	857					
24	4Q11	960	722					
25	1Q12	1110	1342					
26	2Q12	1125	1066					
27	3Q12	1147	1422					
28	4Q12	486	1326					
29	1Q13	949	1078					
30	2Q13	342	795					
31	3Q13	1096	674					
32								
33								
34								
35								
Coefficient of Variation:		0.44	0.23					
Mann-Kendall Statistic (S):		-23	-35					
Confidence Factor:		65.1%	71.7%					
Concentration Trend:		Stable	Stable					



Notes:
1. At least four independent sampling events per well are required for calculating the trend. *Methodology is valid for 4 to 40 samples.*
2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C.J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.
4. Grey results indicate that the analyte was not detected above the reporting limit shown.

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January 2014

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2014 PERIODIC TECHNICAL REVIEW
OF LONG-TERM MONITORING PROGRAM

Solutia Inc.
W.G. Krummrich Facility
Sauget, Illinois

Attachments

Attachment 2

Truex et al., 2006: Geochemical Conditions (Select Pages)

WSRC-STI-2006-00096, Rev. 0

Key Words:
Environment
Remediation

Retention:
Permanent

Scenarios Evaluation Tool for Chlorinated Solvent MNA

(A Research Study of the Monitored Natural Attenuation/Enhanced Attenuation for Chlorinated Solvents Technology Alternative Project)

August 16, 2006

Washington Savannah River Company
Savannah River Site
Aiken, SC 29808

Prepared for the U.S. Department of Energy Under Contract Number DEAC09-96-SR18500

SRNL
SAVANNAH RIVER NATIONAL LABORATORY

Detailed Method: A more detailed method for evaluating which hydrogeologic setting best matches your plume segment is based on the U.S. EPA's DRASTIC system (Allen et al., 1987). DRASTIC includes a description of 88 hydrogeologic settings that can also be used as a resource for selecting a scenario. Appendix 1 contains a decision tree to select one of the 88 different DRASTIC settings, and shows which of the five hydrogeologic settings for this scenarios document best match each DRASTIC setting (see Appendix 1).

KEY POINTS:

Hydrogeology is a primary factor and is based on groundwater velocity and the complexity of the geologic system.

2.2 Geochemical Setting

The geochemical setting drives the types of degradation reactions that are present in a particular plume segment. As discussed in each scenario, it is important to understand the natural attenuation processes to manage the plume using MNA. The geochemical setting is also important for assessing the type of enhancement that may be required when degradation reactions are not sufficient under natural conditions. Section 5 contains additional information on the specific types of degradation reactions that can be expected to occur under each geochemical condition.

How to Pick A Geochemical Setting

To apply the scenarios approach, one of the following three geochemical environments must be selected for your plume segment using the following simple rules (Table 3):

TABLE 3. Geochemical Settings in Scenarios Approach

Geochemical Environment	Description (see note below about use of these values)
G1. Anaerobic	Average dissolved oxygen concentration < ~1 mg/L (if meter) or < ~0.5 mg/L (if test kit); **AND** Sulfate concentration < ~ 50 mg/L; (value applies to most but not all sites) **AND** Nitrate < ~1 mg/L; **AND** Methane OR ferrous iron OR sulfide must be detected in most of the wells; **AND** TOC > ~5 mg/L; **AND** Dechlorination products must be present in the plume
G2. Anoxic	Average dissolved oxygen concentration < ~2 mg/L (by meter or by test kit); **AND** Plume doesn't meet all of the anaerobic indicators
G3. Aerobic	Average dissolved oxygen concentration > ~2 mg/L (by meter or by test kit); **AND** Plume doesn't meet ANY of the anaerobic indicators

With these criteria, a plume can be classified as Anaerobic, Anoxic, or Aerobic.

NOTE: *All criteria listed for a geochemical category must generally be satisfied to be selected as the geochemical setting. The criteria statements and numeric values should not be used as absolute rules. Technical judgment and knowledge of site conditions should be applied in conjunction with these guidelines when determining the site geochemical setting.*

KEY POINT:

Geochemistry is a primary factor and is used to determine if your plume segment is aerobic, anaerobic, or anoxic.

Modification to Methodology for This Project:

Anaerobic conditions were defined as containing (in addition to the requirements stated above):

Sulfate concentrations < ~50 mg/L

OR

Methane concentrations > 100 ug/L

This modification was based on more recent experience with methanogenesis conditions at sites.

January 2014

2014 PERIODIC TECHNICAL REVIEW OF LONG-TERM MONITORING PROGRAM

Solutia Inc.
W.G. Krummrich Facility
Sauget, Illinois

Attachments

Attachment 3

Northern Plume Stability Analysis

NORTHERN PLUME STABILITY ANALYSIS
SOLUTIA INC.
W.G. KRUMMRICH FACILITY
SAUGET, ILLINOIS

1.0 RELEVANT BACKGROUND INFORMATION

Monitoring activities have been performed since the third quarter of 2011 to characterize and understand the behavior of benzene and chlorobenzene in groundwater in the Deep Hydrologic Unit (DHU) in the area north of the W.G. Krummrich Facility (Figures A3.1 and A3.2).

1.1 Hydrogeologic Conceptual Model for Northern Plume

The area between monitoring well GWE-5D and the Illinois Department of Transportation (IDOT) highway dewatering wells to the north is characterized by changing groundwater flow directions that are controlled by Mississippi River elevation, pumping regime of the highway dewatering wells, and local hydrogeologic conditions.

Sustained periods with a northerly flow component over several consecutive quarters were not observed. A northerly flow component was only detected in seven of the past 20 quarterly monitoring events. Five of the seven quarters with northerly groundwater flow were preceded and followed by quarters that showed more direct flow westward from the W.G. Krummrich Facility to the river.

Overall, this analysis supports a conceptual model where the area north of the W.G. Krummrich Facility has a dynamic groundwater flow system, with some limited, intermittent northerly flow during certain periods of rapidly rising river levels (bank recharge conditions). Even during high river periods, groundwater flow to the north is relatively slow if the high river levels are sustained over several weeks. Under these conditions, more stagnant groundwater flow conditions are observed in the area.

1.2 IDOT Dewatering System

The IDOT dewatering activities associated with highway interchanges in East St. Louis have been managed by four groups of wells: Missouri Ave., I-70, I-64, and 25th Street. Each system has multiple wells, and each well is paired with a separate observation well, five linear feet away from the pumping well, to measure water levels. The location of the dewatering system closest to the northern plume, the Missouri Ave. system, is shown in Figures A3.1 and A3.2.

The overall pumping rate of all four systems is about 8,300 gallons per minute (gpm) except during high flood stage of the Mississippi River (TBirdie, 2009). The pumping rate of the Missouri Ave. system is related to the Mississippi River elevation, with estimated pumping rates of 5,000 gpm or more for river levels greater than 415 ft Mean Sea Level (MSL), and minimum pumping rates of about 2,500 gpm for river levels at 380 ft MSL (TBirdie, 2009).

1.3 Groundwater Monitoring System

The current groundwater monitoring system for the northern plume is comprised of five wells: GWE-3D and 5D and ESL-MW-A, C1, and D1 (Figure A3.1 and A3.2). All five wells are screened in the DHU.

2.0 INTERPRETATION AND ANALYSIS

2.1 Effect of River Elevation on Plume Dynamics

The groundwater flow pattern in the area between the W.G. Krummrich Facility, IDOT wells, and the Mississippi River changes over time based on several factors including precipitation/recharge events, pumping regime of the IDOT dewatering wells, and most importantly, the recent Mississippi River elevation and pattern in recent river elevation (i.e., rising, falling, or stable). Figures A3.3 through A3.6 show four examples of different groundwater flow regimes based on four different Mississippi River elevations and recent river level patterns (see Table 1 of main report):

- Figure A3.3 (potentiometric surface measured on July 31, 2013) shows more typical conditions, with the river elevation falling to 387.4 ft MSL (40^{th} percentile high flow). Groundwater from the W.G. Krummrich Facility flows mostly west to the River.
- Figure A3.4 (potentiometric surface measured on February 15, 2013) shows groundwater elevations at a relatively stable river level (385.2 ft MSL, or a 24^{th} percentile high flow) and a pronounced groundwater flow direction directly to the river.
- Figure A3.5 (potentiometric surface measured on March 14, 2013) shows a rapidly rising Mississippi River elevation to a relatively high level (404.3 ft MSL, or a 93^{rd} percentile high flow). There is an apparent northerly groundwater flow component from the northern border of the W.G. Krummrich Facility along with flow from the river into the aquifer (bank recharge).
- Figure A3.6 (potentiometric surface measured on August 12, 2011) shows a high, but relatively stable groundwater level condition measured with a 401.7 ft MSL river elevation, or a 88^{th} percentile high flow). While there is a northerly flow component on the northern boundary of the W.G. Krummrich Facility, the overall hydraulic gradients are low, indicating semi-stagnant groundwater flow conditions across the mapped area.

An analysis of 20 quarterly Mississippi River potentiometric surface maps (from 4th Quarter 2008 to 3rd Quarter 2013, data shown in Table A3.1) by URS Corporation (URS) and GSI Environmental Inc. (GSI) indicates that the northerly flow component was present 35% of the time (seven of the twenty quarters), but only occurred when the river elevation was 396.7 ft MSL or higher. Because this five-year period was a period of higher-than-average flow (average river elevation during this period was 394.1 ft MSL, or a 66th percentile flow), the actual frequency of the northerly flow component is likely to be lower (for example, the apparent minimum flow level where a northerly flow component was observed was 396.7 ft MSL, which only occurs 24% of the time).

As shown in Figure A3.6, a high river elevation alone does not result in high-gradient groundwater flow to the north: while the river is extremely high (88th percentile high flow), there is only a weak hydraulic gradient to the north from the W.G. Krummrich Facility (0.00042 ft/ft from the 402 ft MSL contour north to the 401 ft MSL contour), or about one-third the average westerly gradient that is typically observed between the plant and the river (0.0013 ft/ft). Figure A3.5 also shows a relatively weak northern gradient in this area during high river flow: 0.00079 ft/ft to the 386 ft MSL contour. The highest gradients occur during periods of high regional groundwater levels and low river elevations (for example, Figure A3.3 shows a gradient of 0.031 ft/ft).

Hourly data were collected with a pressure transducer in one well (ESL-MW-A) from Nov. 17, 2012 to March 15, 2013 (Figure A3.7). These data show the groundwater levels in this area of the aquifer react to the Mississippi river levels but in a damped, smoothed fashion with a lag of about a week. For example, a local minimum of 375.4 ft MSL was observed in the Mississippi River elevation data on January 26, 2013, after which the river rose and maintained a water level several feet over this minimum. The groundwater elevation in well ESL-MW-A did not increase above a 0.1 ft threshold until February 2, 2013, seven days later. These data support the conclusion that the hydraulic connection between the river and plume create a dynamic plume boundary that shifts back and forth.

2.2 Groundwater Monitoring Results for Northern Plume

Sampling performed in the third quarter of 2013 (Table A3.2) showed two of the northern plume wells with non-detect values for benzene and chlorobenzene, and three with detectable benzene and chlorobenzene concentrations. These three wells had sufficient data to perform a Mann-Kendall analysis for chlorobenzene (Figure A3.8) and showed a decreasing trend in well GWE-5D, stable in well ESL-MW-D1, and no trend in well GWE-3D. When concentrations of two northern wells with the longest sampling records (GWE-3D and GWE-5D starting in August 2011) are averaged (geometric mean), their Mann-Kendall statistical trend is designated as stable.

Methane is detected in all the northern plume wells, with higher concentrations associated with higher chlorobenzene concentrations (up to 2,000 ug/L) (Table A3.3). This is likely related to the anaerobic biodegradation of chlorobenzene under methanogenic conditions.

Benzene concentrations were much lower than the chlorobenzene concentrations, and may be a degradation product of chlorobenzene reductive dechlorination in this area or possibly sources other than the W. G. Krummrich Facility.

2.3 IDOT Dewatering System Monitoring Results

Groundwater sampling has also been performed by IDOT in the six observation wells in the Missouri Ave. dewatering system monthly since January 2013, but with no detects for benzene or chlorobenzene (personal communications, Steve Gobelman, IDOT, to Mark Haddock, Golder Associates, 2013).

Sampling of the combined dewatering system outfall for volatile organic compounds has been conducted quarterly from April 2011 to at least January 2013 (Andrews Engineering, 2013). Estimated values (“J Flag”) for chlorobenzene have been detected on three sampling events, but at very low levels (0.0012J to 0.0029J ug/L) about 30 to 100 times below the 0.1 ug/L maximum contaminant level (MCL) for chlorobenzene.

3.0 CONCLUSIONS

- There are no statistically significant increasing trends for benzene or chlorobenzene in any of the northern plume monitoring wells over the last two years.
- The average chlorobenzene concentration of wells (GWE-5D and GWE-3D) with the longest monitoring records (from 4th Quarter 2011) shows a stable pattern over time. No statistically significant increasing trend is observed even with a very significant high river event (up to 411 ft MSL) in 2nd Quarter 2013.
- There is no sustained northerly gradient, only intermittent northerly flow as indicated by the four example potentiometric surface maps. An evaluation of 20 quarterly potentiometric surface maps indicates this northerly gradient is typically ≤ 50% of the average westerly hydraulic gradient towards the river (0.0013 ft/ft), and is only present 25% of the time based on the river levels when the northerly gradient occurred.
- There have never been any benzene or chlorobenzene detects in the IDOT observation wells since monthly sampling began in January 2013.
- Proven degradation mechanisms in the observed geochemical environment are anaerobic degradation for both benzene and chlorobenzene (see Section 4.2.2 of the 2013 Periodic Technical Review).
- Indirect geochemical evidence of anaerobic biodegradation of chlorobenzene is seen with higher concentrations of methane in wells correlated with higher concentrations of chlorobenzene.

4.0 RECOMMENDATION

The northern plume has been determined to be stable based on quarterly data collected since at least the fourth quarter of 2012 and over a broad range of river levels. However, Solutia recommends sampling wells GWE-3D and 5D and ESL-MW-A, C1, and D1 in February 2014 and February 2015. These additional data will provide a sufficient population (at least three years of data) for a reliable statistical determination of northern plume stability. Quarterly sampling is not required to assess the stability trend if sampling is regularly performed during relatively stable river conditions, such as have historically been observed in February.

5.0 REFERENCES

Andrews Engineering, 2013. Missouri Avenue Well Field / Bowman Yard Outfall, Andrews Engineering, Inc., Springfield, Illinois, March 2013.

Gobelman, S., IDOT, to Mark Haddock, Golder Associates, 2013. Personal communication.

TBirdie, 2009. Computer Simulation of Groundwater Flow Illinois Department of Transportation Dewatering Wellfield, East Saint Louis, Illinois, TBirdie Consulting, Inc. Lawrence, KS, March 26, 2009.

Table A3.1
Surface Water and Groundwater Elevations
2008 through 2013
Supplemental Monitoring Wells

Quarter	Date	Mississippi River Elevation[1] (ft NAVD 88)	ESL-MW-A[2]	ESL-MW-C1[2]	ESL-MW-D1[2]	GWE-3D	GWE-4D	GWE-5D[2]
3Q08	08/18/08	386.79	-	-	-	NG	397.84	-
4Q08	11/17/08	386.24	-	-	-	NG	393.49	-
1Q09	02/23/09	389.00	-	-	-	NG	392.32	-
2Q09	05/29/09	403.95	-	-	-	NG	401.09	-
3Q09	08/17/09	387.05	-	-	-	NG	394.24	-
4Q09	11/13/09	400.49	-	-	-	NG	399.06	-
1Q10	02/12/10	390.97	-	-	-	NG	396.82	-
2Q10	05/14/10	406.25	-	-	-	NG	400.20	-
3Q10	09/15/10	394.91	-	-	-	NG	399.17	-
4Q10	11/22/10	392.10	-	-	-	NG	396.04	-
1Q11	02/21/11	385.24	-	-	-	NG	391.19	-
2Q11	05/17/11	406.64	-	-	-	NG	402.44	-
3Q11	08/11/11	401.22	-	-	-	400.81	401.18	-
4Q11	11/10/11	386.43	-	-	-	390.23	392.21	389.95
1Q12	02/09/12	387.25	-	-	-	389.32	390.79	389.58
2Q12	05/03/12	396.73	-	-	-	393.42	393.92	393.04
3Q12	08/09/12	380.58	-	-	-	387.69	389.90	388.53
4Q12 - Oct	10/16/12	380.44	-	-	-	384.41	386.64	385.48
4Q12 - Nov	11/15/12	380.32	386.02	387.72	385.18	384.48	386.26	385.20
4Q12 - Dec	12/20/12	378.20	385.28	387.06	384.32	383.66	385.46	384.46
1Q13 - Jan	01/17/13	377.45	384.72	386.45	383.73	383.03	384.84	383.83
1Q13 - Feb	02/14/13	384.84	385.95	386.34	384.24	383.94	385.29	384.36
1Q13 - Mar	03/14/13	403.24	385.94	386.82	385.78	386.45	386.26	385.79
2Q13	05/09/13	410.83	395.69	393.99	397.47	400.94	398.99	398.78
3Q13	07/30/13	386.55	395.85	396.18	395.49	395.40	397.56	395.98

Notes:

1. The Mississippi River stage elevation presented is an average elevation for the days of the quarterly gauging event. River elevations were collected from an electronic gauge (USGS 07010000) located at River Mile 180.0 on the Eads Bridge or from the Site R Bubbler.
2. GWE-5D was not installed until Fourth Quarter of 2011 and ESL-MW-A, ESL-MW-C1, and ESL-MW-D1 were not installed until the Fourth Quarter of 2012

NG - Not gauged

Table A3.2

Groundwater Concentrations - 2011 through 2013

Benzene and Chlorobenzene

Supplemental LTM Wells

Quarter	Sample Date	Benzene Result (µg/L)	Chlorobenzene Result (µg/L)
ESL-MW-A			
4Q12	11/20/2012	< 1	2.2
1Q13	2/21/2013	1.1	< 1
2Q13	5/17/2013	1.4	< 1
3Q13	8/7/2013	< 1	1
ESL-MW-C1			
4Q12	11/20/2012	< 1	3.2
1Q13	2/21/2013	< 1	1.3
2Q13	5/17/2013	1.4	< 1
3Q13	8/7/2013	< 1	< 1
ESL-MW-D1			
4Q12	11/20/2012	35	1,800
1Q13	2/20/2013	65	2,400
2Q13	5/17/2013	46	2,400
3Q13	8/7/2013	32	1,300
GWE-3D			
3Q11	8/31/2011	< 10	630
4Q11	12/6/2011	11	1,200
1Q12	2/20/2012	< 10	1,200
2Q12	5/17/2012	< 10	1,000
1Q13	3/1/2013	10	560
2Q13	5/16/2013	37	1,900
3Q13	8/6/2013	50	2,500
GWE-5D			
4Q11	12/5/2011	53	1600 D
1Q12	2/20/2012	86	1,900
2Q12	5/21/2012	47	980
3Q12	8/15/2012	24	510
4Q12	11/19/2012	4.8	150
1Q13	2/20/2013	4.5	96
2Q13	5/17/2013	8.4	250
3Q13	8/7/2013	14	460

Notes:

µg/L = micrograms per liter

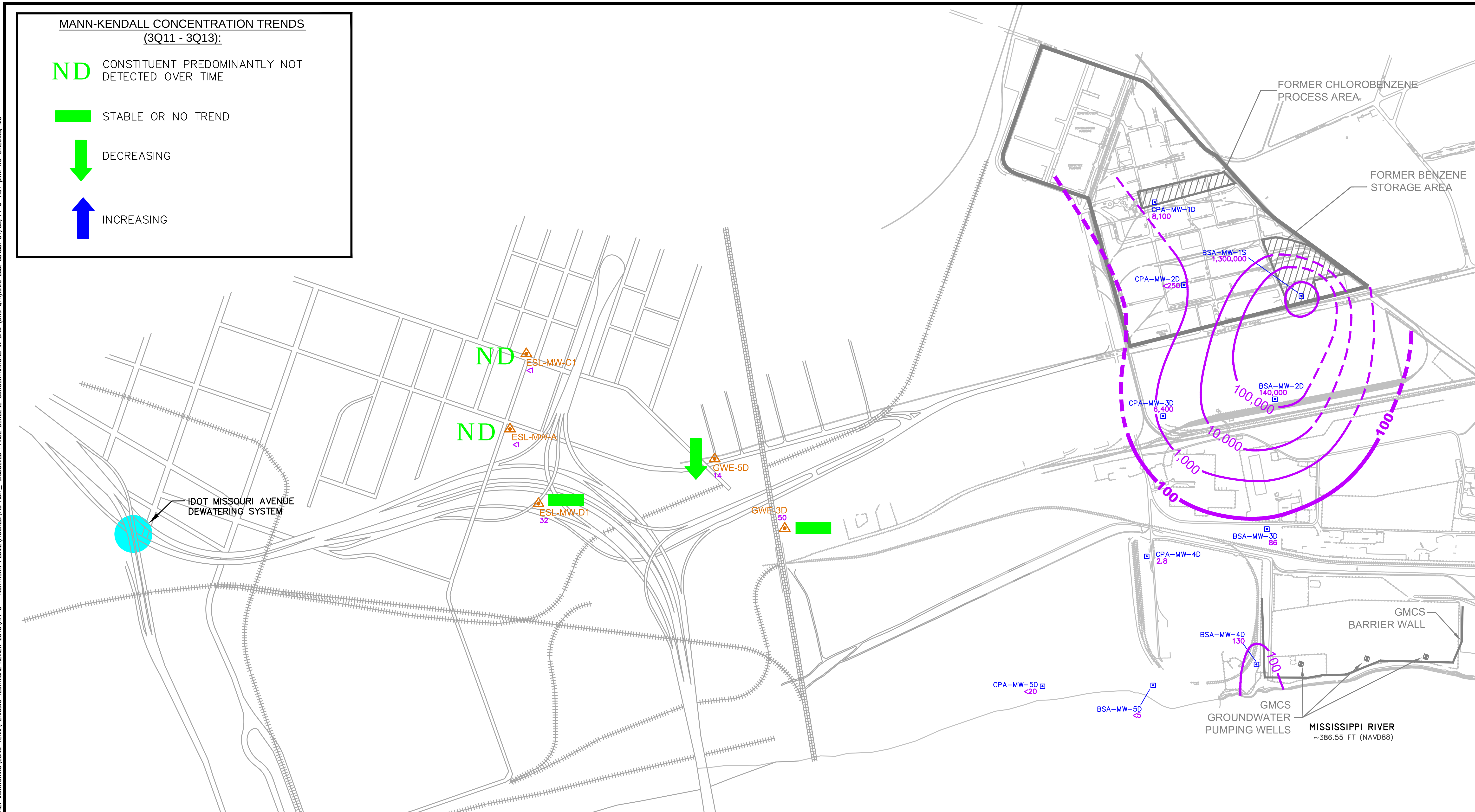
< = Result is non-detect

D = Compound analyzed at a dilution

Table A3.3
Geochemical Parameters
2011 through 2013
Supplemental LTM Wells

Quarter	Sample Date	Dissolved Oxygen (mg/L)	ORP (mV)	Methane (ug/L)	Sulfate as SO4 (mg/L)	Nitrogen, Nitrate (mg/L)	Total Organic Carbon (mg/L)	Chloride (mg/L)	Conductivity (ms/cm)	Ferrous Iron (mg/L)	pH (SU)	Temperature (°C)
ESL-MW-A												
4Q12	11/20/12	0.04	-262	2.2	710	<0.05	4.3	94	1.785	>3.3	6.91	16.88
1Q13	02/21/13	-0.04	-113	3.2	630		3.5	93	2.144	16	6.85	14.85
2Q13	05/17/13	-0.03	-111	7.1	670	<0.05	2.8	96	1.989	>3.3	6.95	16.28
3Q13	08/07/13	0.03	-107	9.1		<0.05	3.3	97	2.047	>3.3	6.94	16.36
ESL-MW-C1												
4Q12	11/20/12	0.02	-468	12	890	<0.05	5.3	97	1.99	>3.3	7.16	16.11
1Q13	02/21/13	-0.02	-89	2.4	920		4	98	2.374	12	6.9	15.39
2Q13	05/17/13	0.04	-111	4.2	1,000	<0.05	4	100	2.452	>3.3	6.96	15.94
3Q13	08/07/13	-0.03	-112	<0.58		0.11	4.1	99	2.404	>3.3	6.95	16.46
ESL-MW-D1												
4Q12	11/20/12	0.03	-233	260	660	<0.05	4.3	130	1.825	>3.3	6.86	17.11
1Q13	02/20/13	0.11	-111	240	580		4	150	2.272	14	6.79	13.24
2Q13	05/17/13	0.01	-112	300	580	<0.05	3.4	140	2.096	>3.3	6.9	16.77
3Q13	08/07/13	-0.01	-116	49		<0.05	3.3	120	1.979	>3.3	6.93	17.03
GWE-3D												
3Q11	08/31/11	0.24	-152.7	16	170	<0.05	3	60	1.358	>3.3	6.53	16.95
4Q11	12/06/11	-0.06	176.78				2.8	59	2.745	>3.3	6.92	14.49
1Q12	02/20/12	0.04	-87.12	33	220	0.13	3	60	1.419	>3.3	6.93	14.81
2Q12	05/17/12	0.41	-85.06	59	250	<0.05	3	95	1.202	>3.3	6.93	16.44
1Q13	03/01/13			31	170	<0.05	11	93		>3.3		
2Q13	05/16/13	0.14	-146	230	230	<0.05	4.5	510	2.677	>3.3	6.84	16.14
3Q13	08/06/13	-0.05	-145	260	400	0.05	5.2	1100	4.378	>3.3	6.95	16.32
GWE-5D												
4Q11	12/05/11	-0.21	75	58	280	<0.05	16	89	2.385	>3.3	6.8	15.83
1Q12	02/20/12	0.00	-191.35	230	330	<0.05	3.9	96	1.45	>3.3	6.87	15.44
2Q12	05/21/12	0.32	-7.5	160	390	<0.05	3.3	90	1.397	>3.3	7.01	17.48
3Q12	08/15/12	-0.11	-290	230	460	<0.05	3.3	81	1.457	>3.3	6.86	17.58
4Q12	11/19/12	0.00	-216	51	540	<0.05	3.6	84	1.463	>3.3	6.98	15.77
1Q13	02/20/13	0.08	-186	50	460		2.8	93	1.728	15	6.88	13.86
2Q13	05/17/13	-0.01	-162	42	450	<0.05	2.8	87	1.033	>3.3	6.82	17.80
3Q13	08/07/13	-0.01	-141	37		<0.05	3.2	80	1.591	>3.3	6.94	17.95

μg/L = micrograms per liter
mg/L = milligrams per liter
ms/cm = microsiemens per centimeter
mV = millivolts
SU = Standard units
< = Result is non-detect
> = Ferrous iron result exceeds the upper limit of the field colorimeter
J = Estimated detected value
H = Prepped or analyzed outside of specified holding time
DO, ORP, Temperature, Conductivity, and pH were measured in the field using a multi-parameter water quality meter with a flow-thru cell. Values presented represent final measurements before sampling.
Ferrous Iron readings were measured in the field using a Hach DR-890 Colorimeter after the groundwater passed through a 0.2 μm filter
A blank space indicates sample not analyzed for select analyte



LEGEND

- LONG-TERM MONITORING WELL
- SUPPLEMENTAL MONITORING WELL
- 100 — ESTIMATED BENZENE CONCENTRATION CONTOUR (ug/L) IN DHU (ISOCONCENTRATION CONTOURS DASHED WHERE INTERPRETED)

NOTE:
CONTOURS DRAWN BASED ON PROFESSIONAL JUDGEMENT.

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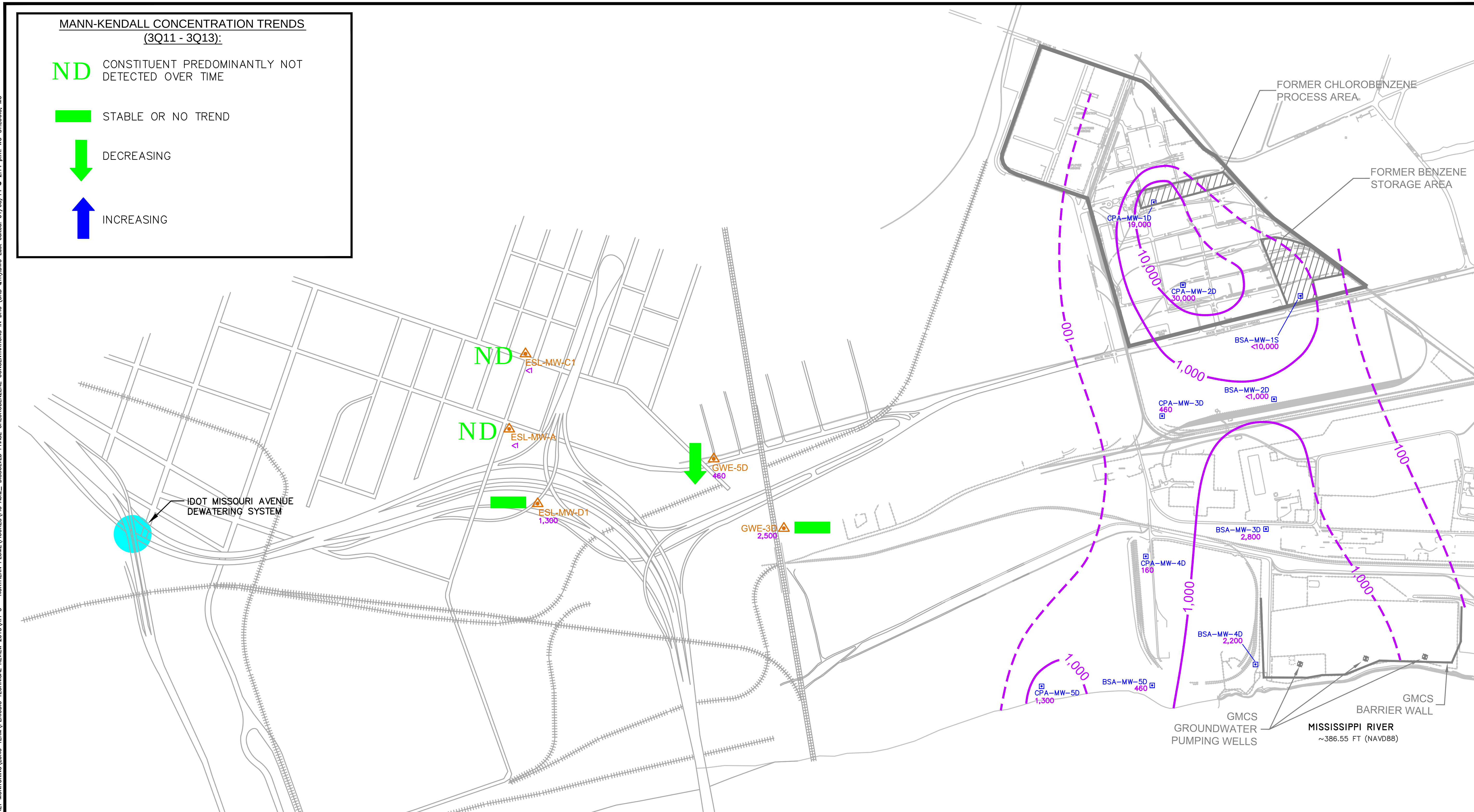
SCALE FEET

2014 NORTHERN PLUME STABILITY ANALYSIS SOLUTIA INC. W.G. KRUMMRICH FACILITY SAUGET, ILLINOIS	PROJECT NO. 21562941
URS	
DRN. BY:djd January 2014 DSGN. BY:nm CHKD. BY:bbb/rt	Dissolved Phase Benzene Concentrations in DHU 3rd Quarter 2013 — FIG. NO. A3.1

File: P:\ENVIRONMENTAL\SOLUTIA WGK\!QUARTERLY MONITORING\LONG-TERM\PERIODIC TECHNICAL REVIEW 2013\ATT 3 - NORTHERN PLUME\FIGURES\FIG A3.1_ DISSOLVED PHASE BENZENE CONCENTRATIONS IN DHU (3RD QTR).DWG Last edited: 01/08/14 @ 1:04 p.m. WC-ST.LOUIS, MO

File: P:\ENVIRONMENTAL\SOLUTIA WGK\QUARTERLY MONITORING\LONG-TERM\PERIODIC TECHNICAL REVIEW 2013\ATT 3 - NORTHERN PLUME\FIGURES\FIG A3.2_ DISSOLVED PHASE CHLOROBENZENE CONCENTRATIONS IN DHU (3RD QTR).DWG Last edited: 01/08/14 @ 2:14 p.m. WC-ST.LOUIS, MO



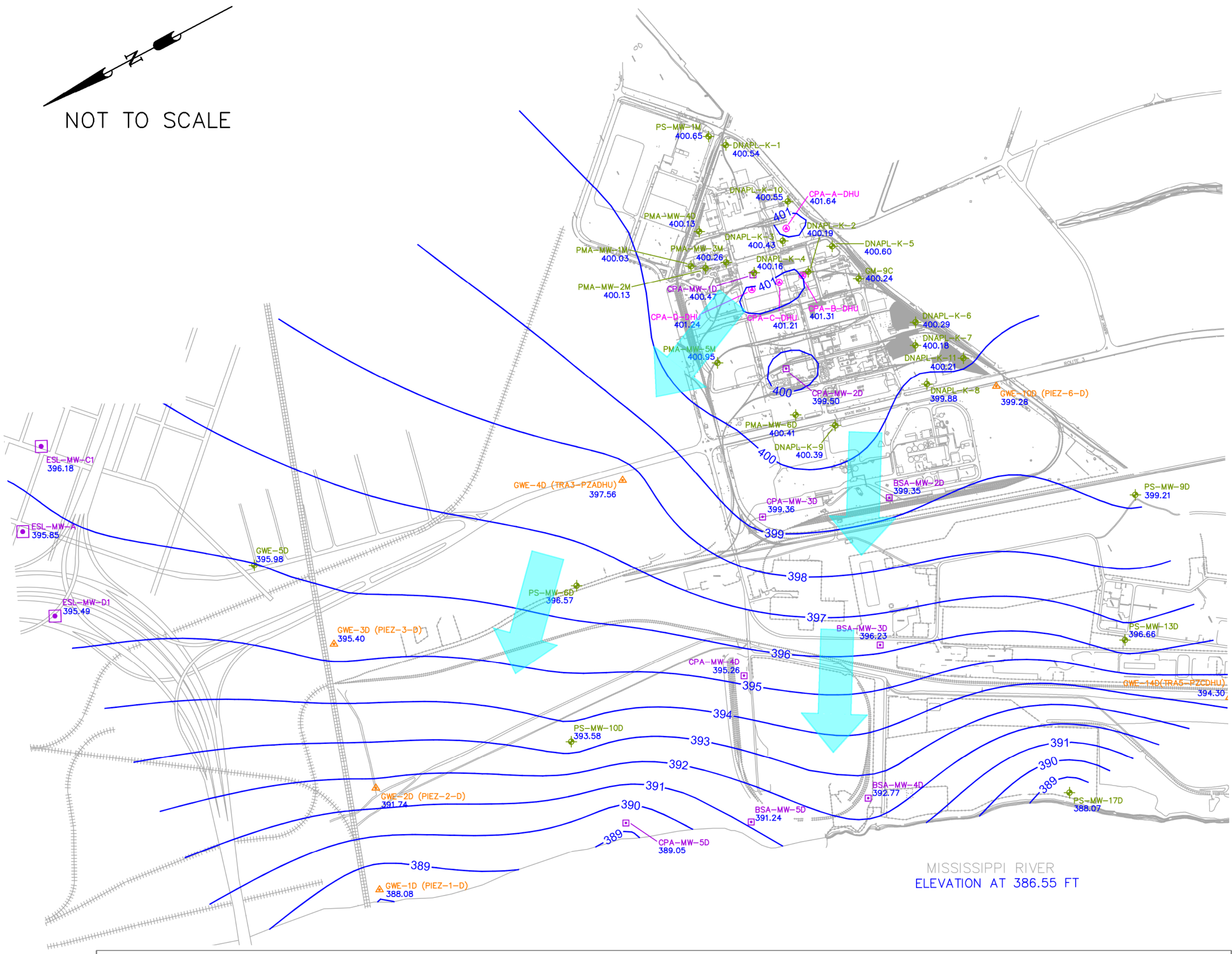
LEGEND

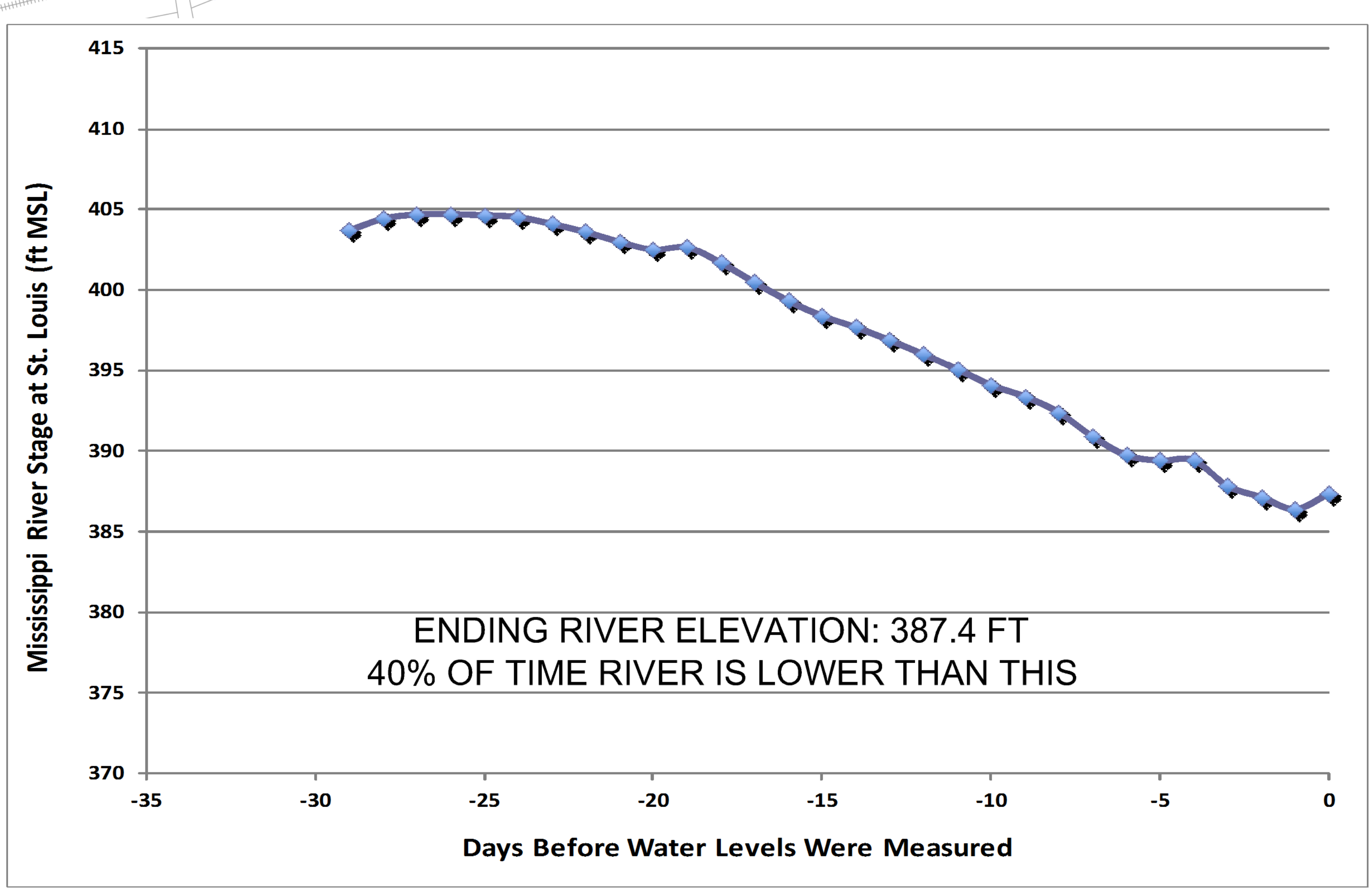
- LONG–TERM MONITORING WELL
- SUPPLEMENTAL MONITORING WELL
- 100 — ESTIMATED CHLOROBENZENE CONCENTRATION CONTOUR (ug/L) IN DHU (ISOCONCENTRATION CONTOURS DASHED WHERE INTERPRETED)

NOTE:
CONTOURS DRAWN BASED ON PROFESSIONAL JUDGEMENT.

2014 NORTHERN PLUME STABILITY ANALYSIS SOLUTIA INC. W.G. KRUMMRICH FACILITY SAUGET, ILLINOIS	PROJECT NO. 21562941
URS	
DRN. BY: djd January 2014 DSGN. BY: nm CHKD. BY: bbb/rt	Dissolved Phase Chlorobenzene Concentrations in DHU 3rd Quarter 2013 — FIG. NO. A3.2

JULY 31, 2013: EXAMPLE OF SUSTAINED DROP IN RIVER LEVEL AND FASTER, MOSTLY WESTERLY GROUNDWATER FLOW TO RIVER



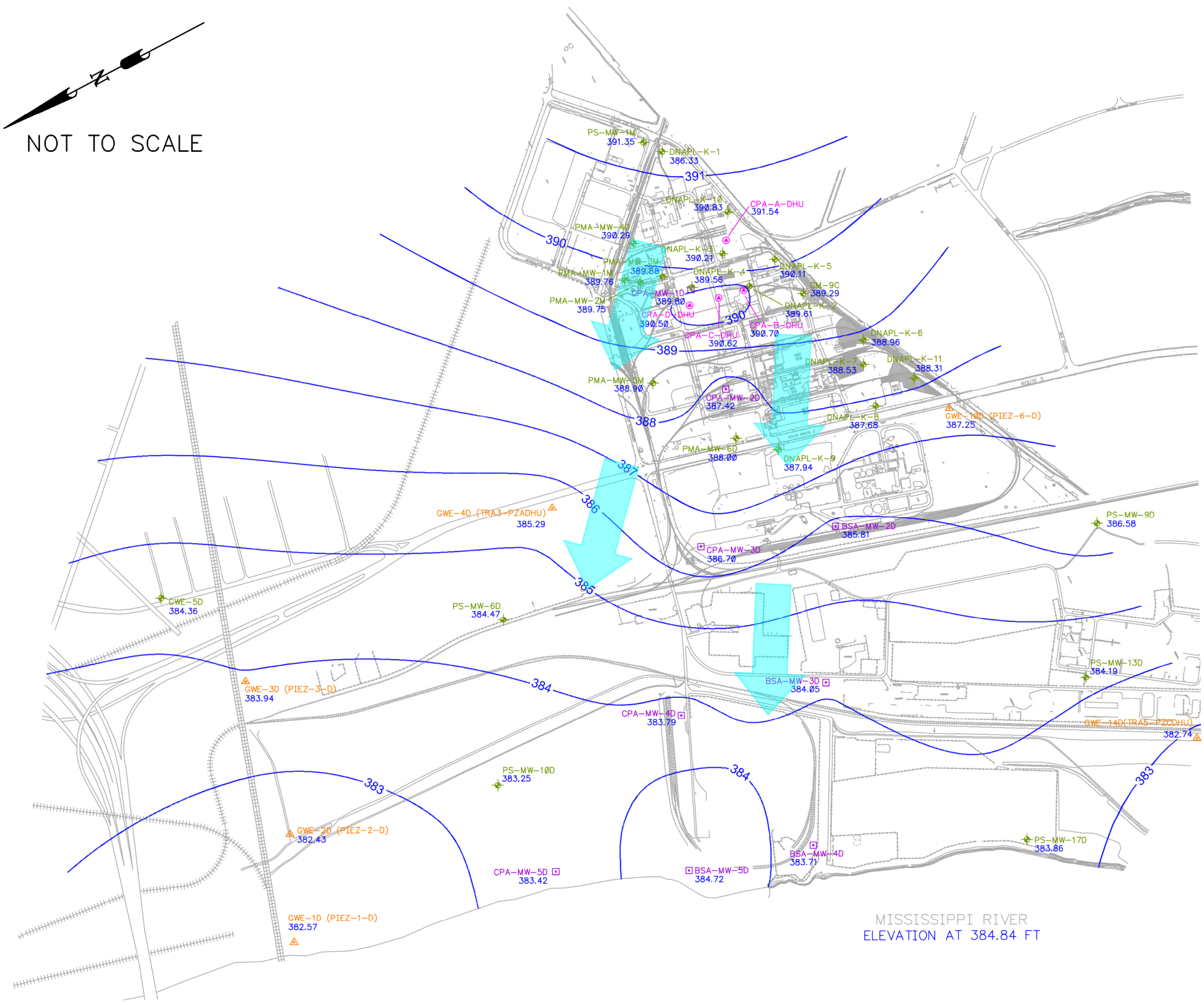


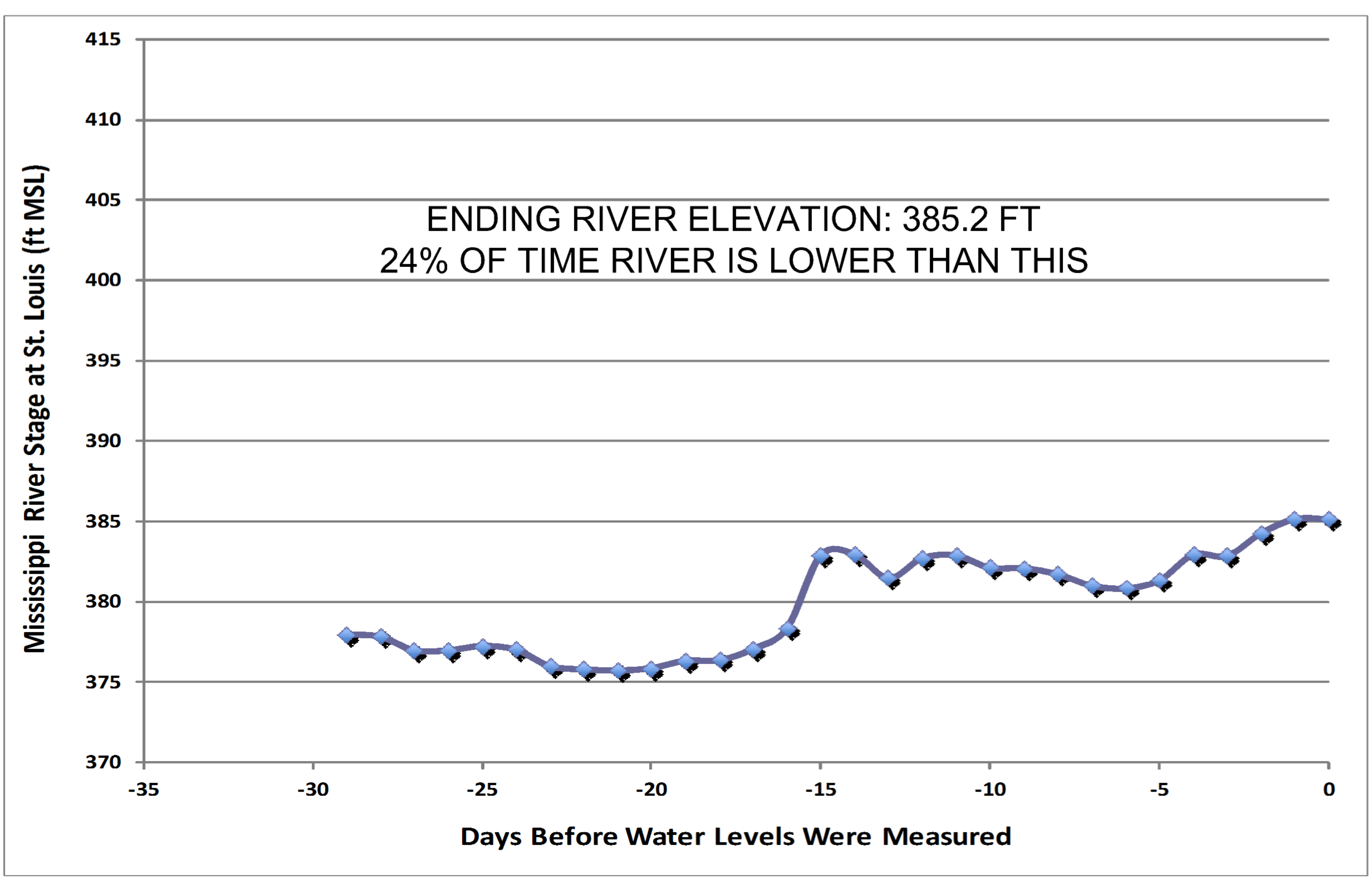
2014 NORTHERN PLUME STABILITY ANALYSIS SOLUTIA INC. W.G. KRUMMRICH FACILITY SAUGET, ILLINOIS	PROJECT NO. 21562941

URS

DRN. BY: djd January 2014 DSGN. BY: nm CHKD. BY: bbb	Groundwater Flow Regimes and Generalized Groundwater Flow Direction—July 31, 2013	FIG. NO. A3.3

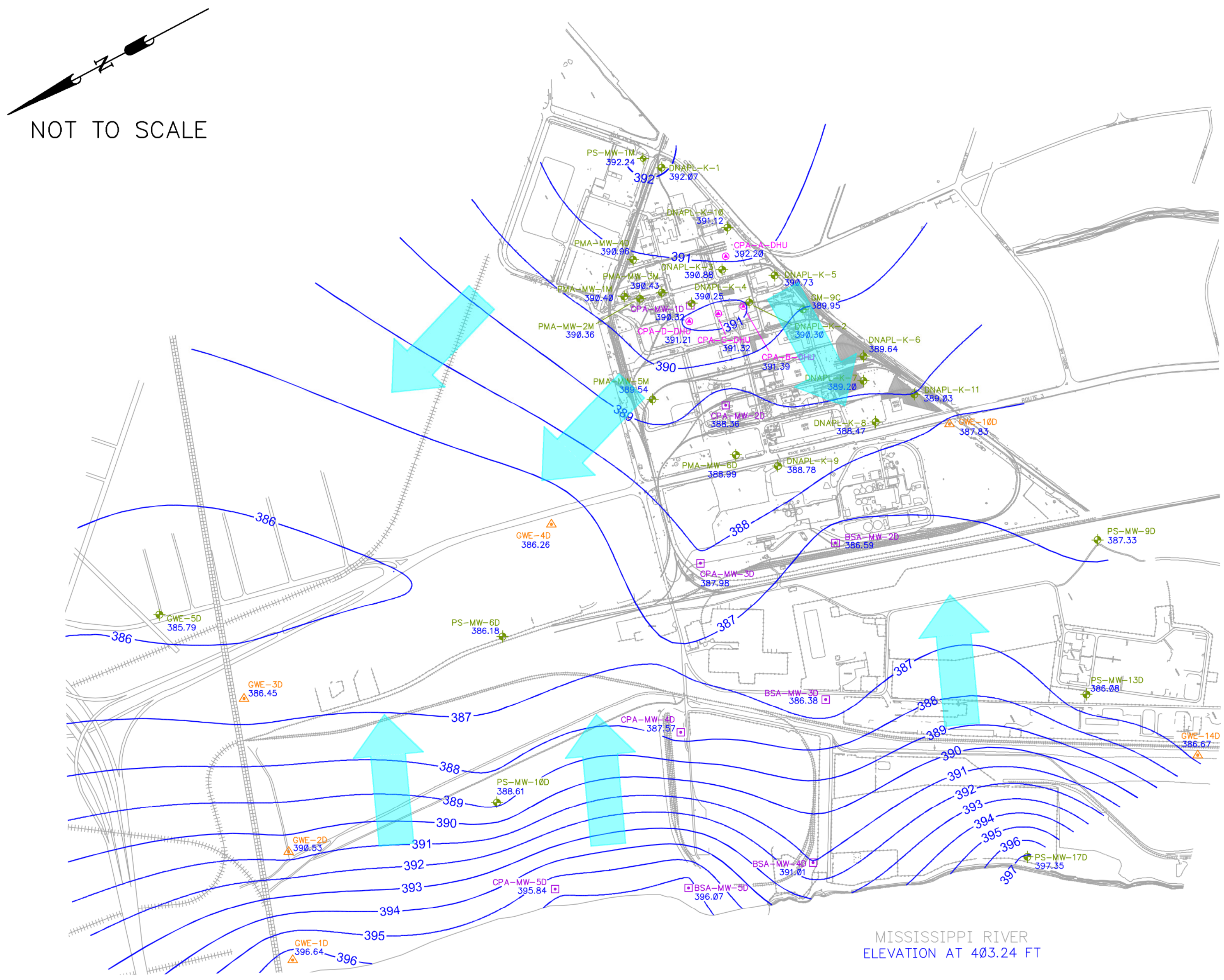
FEBRUARY 15, 2013: EXAMPLE OF SUSTAINED LOW RIVER LEVEL
AND WESTERLY GROUNDWATER FLOW DIRECTLY TO RIVER

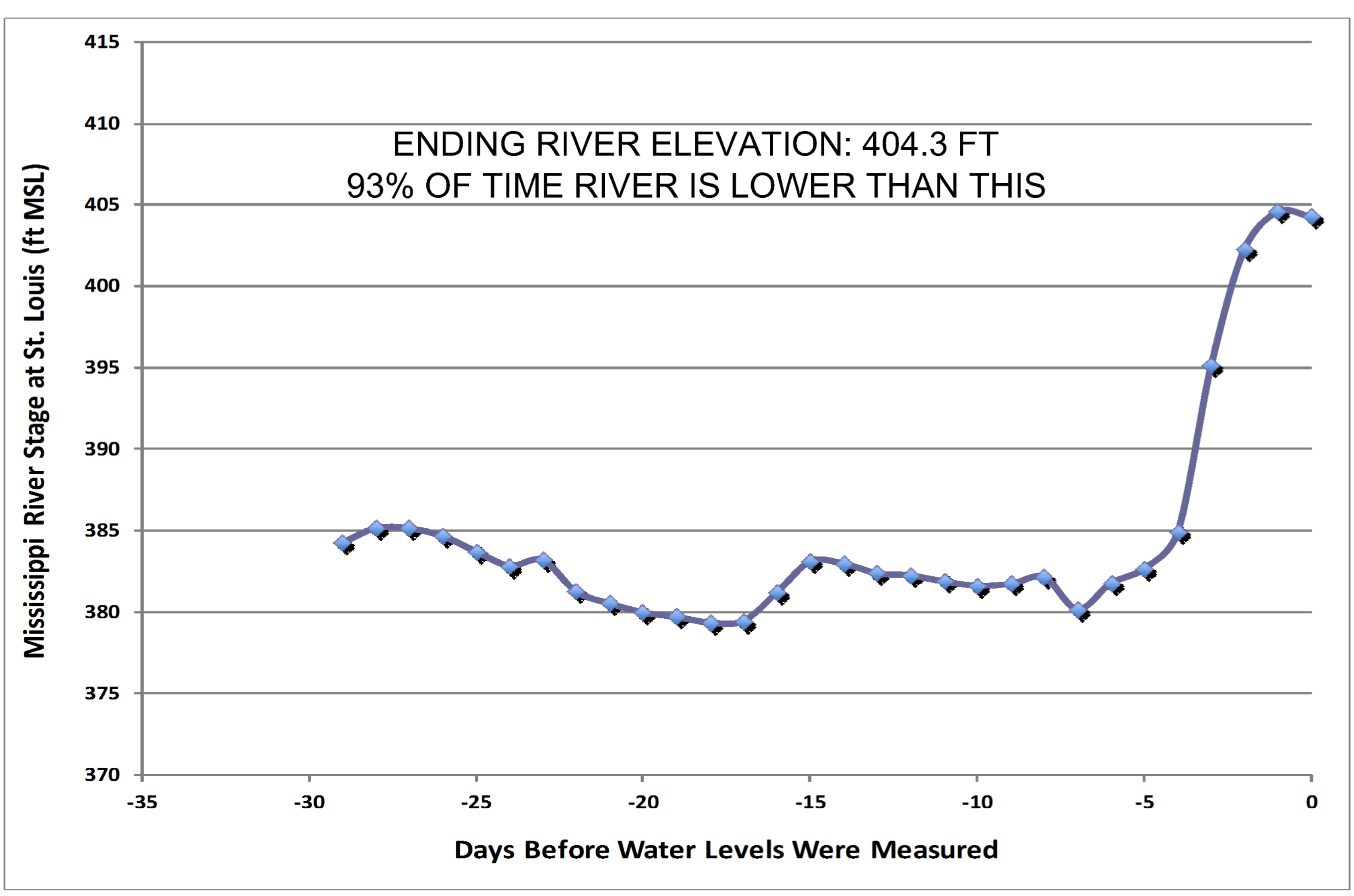




2014 NORTHERN PLUME STABILITY ANALYSIS SOLUTIA INC. W.G. KRUMMRICH FACILITY SAUGET, ILLINOIS		PROJECT NO. 21562941
URS		
DRN. BY: djd January 2014 DSGN. BY: nm CHKD. BY: bbb	Groundwater Flow Regimes and Generalized Groundwater Flow Direction—February 15, 2013	FIG. NO. A3.4

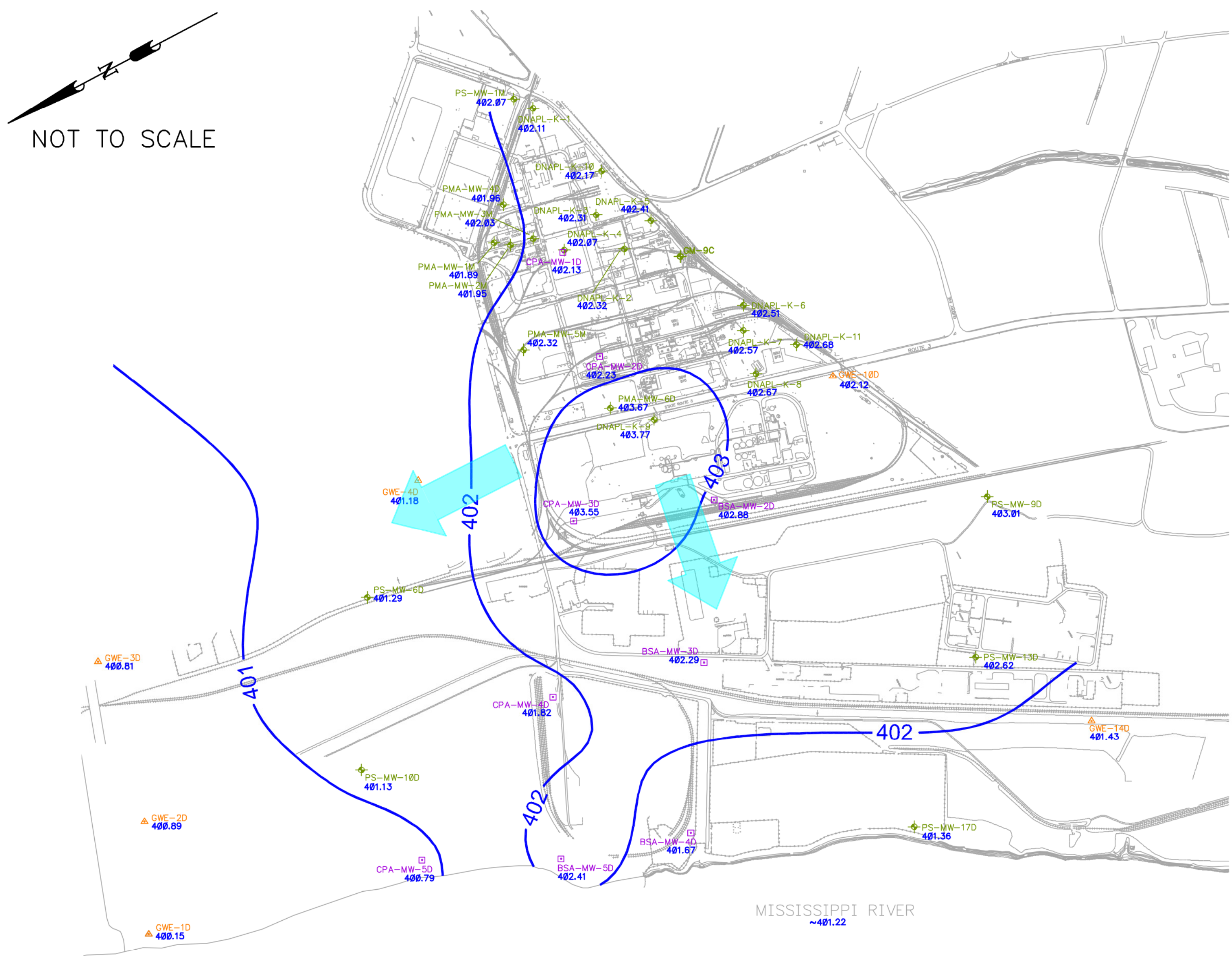
MARCH 14, 2013: EXAMPLE OF RECENT INCREASE IN RIVER LEVEL
WITH FLOW FROM RIVER TO GROUNDWATER AND SOME
NORTHERLY FLOW COMPONENT

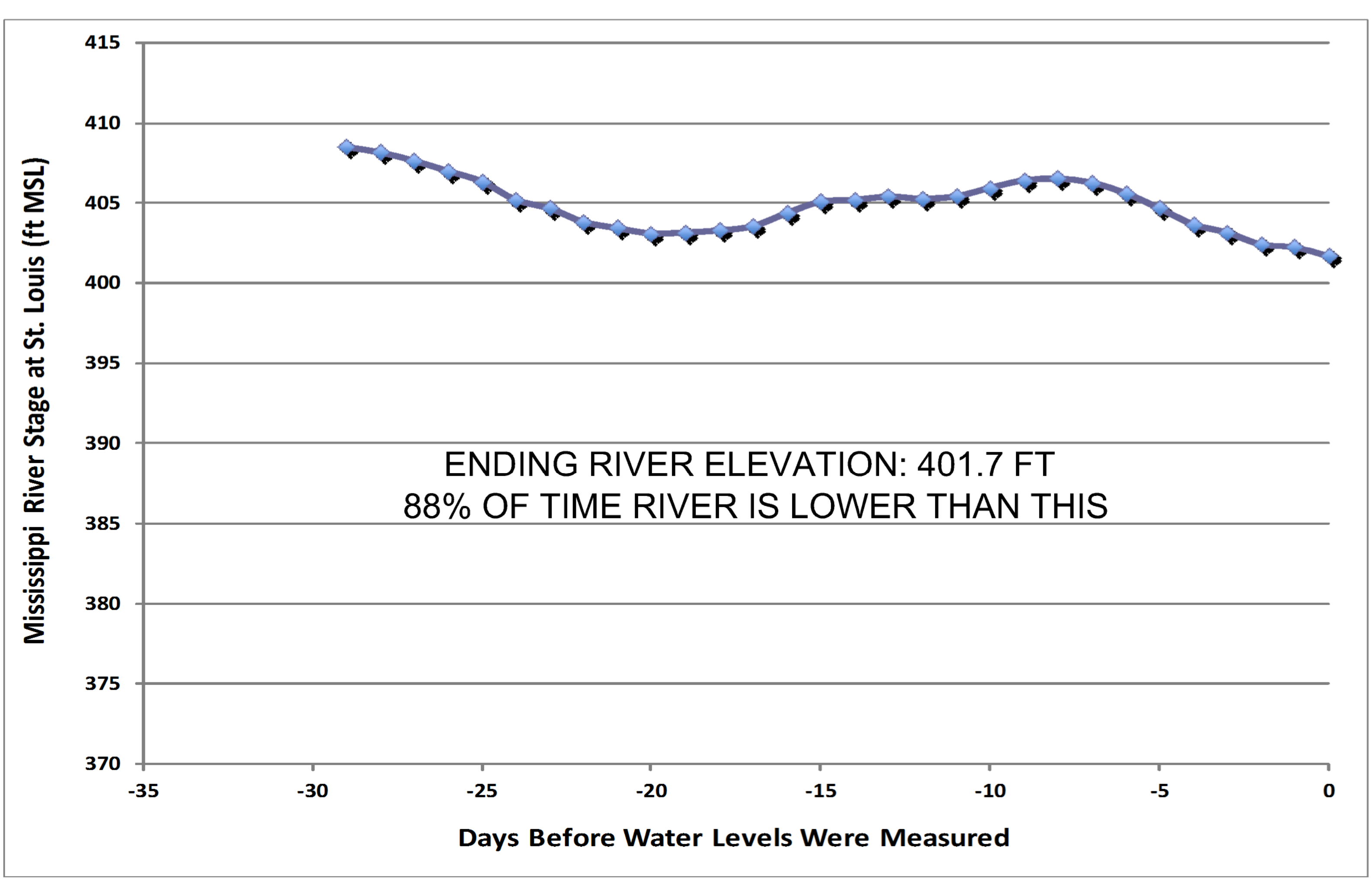




2014 EVALUATION OF THE LONG TERM MONITORING PROGRAM W.G. KRUMMRICH FACILITY SAUGET, ILLINOIS		PROJECT NO. 21562941
URS		
DRN. BY: djd January 2014 DSGN. BY: nm CHKD. BY: bbb	Groundwater Flow Regimes and Generalized Groundwater Flow Direction–March 14, 2013	FIG. NO. A3.5

AUGUST 12, 2011: EXAMPLE OF SUSTAINED HIGH RIVER LEVEL WITH SOME NORTHERLY FLOW BUT LITTLE HYDRAULIC GRADIENT ACROSS SITE





2014 EVALUATION OF THE LONG TERM MONITORING PROGRAM W.G. KRUMMRICH FACILITY SAUGET, ILLINOIS	PROJECT NO. 21562941

URS

DRN. BY: djd January 2014 DSGN. BY: nm CHKD. BY: bbb	Groundwater Flow Regimes and Generalized Groundwater Flow Direction—August 12, 2011	FIG. NO. A3.6

Figure A3.7

Solutia Inc. W.G. Krummrich Facility
Mississippi River and Groundwater Elevations
November 17, 2012 - March 14, 2013

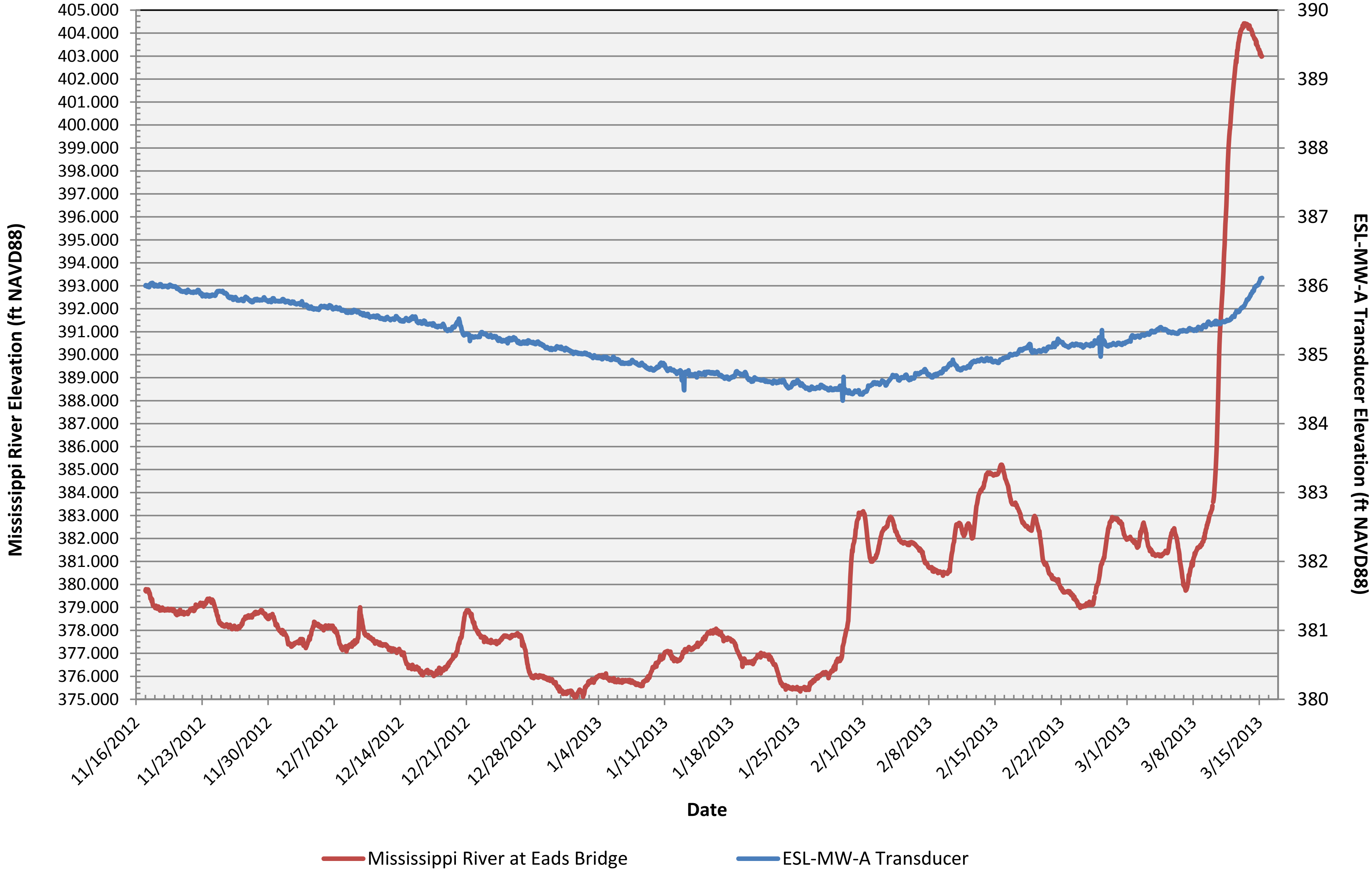
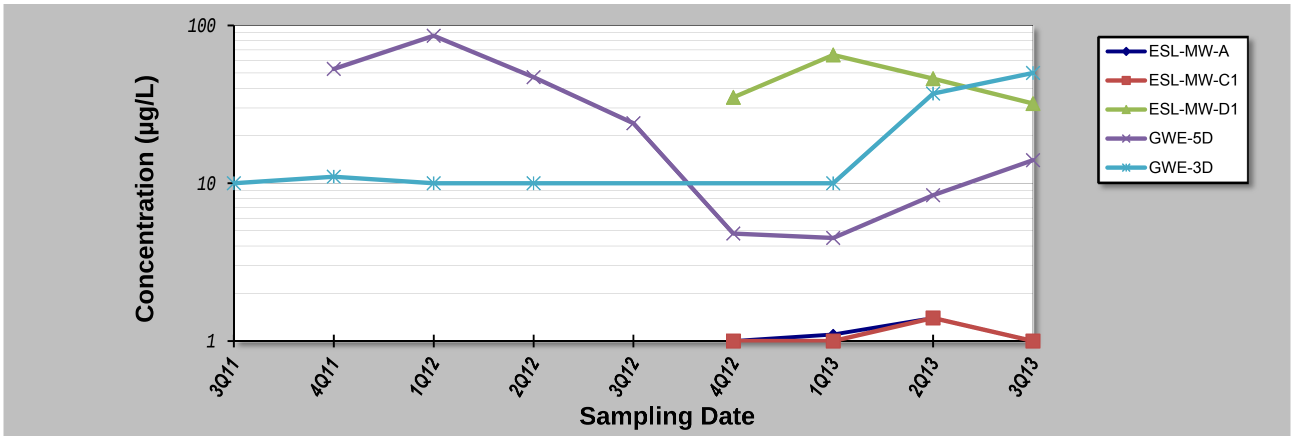


Figure A3.8
Constituent Trend Analysis - The Mann-Kendall Test
Supplemental Monitoring Wells
Benzene

GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date: **November 2013**
Facility Name: **W.G. Krummrich Plant, Sauget, IL**
Conducted By: **Nathan McNurlen - URS Corporation**
Job ID: **21562941**
Constituent: **Benzene**
Concentration Units: **µg/L**

	Sampling Point ID:	ESL-MW-A	ESL-MW-C1	ESL-MW-D1	GWE-5D	GWE-3D		
Sampling Event	Sampling Date	BENZENE CONCENTRATION (µg/L)						
1	3Q11					10		
2	4Q11				53	11		
3	1Q12				86	10		
4	2Q12				47	10		
5	3Q12				24			
6	4Q12	1	1	35	4.8			
7	1Q13	1.1	1	65	4.5	10		
8	2Q13	1.4	1.4	46	8.4	37		
9	3Q13	1	1	32	14	50		
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
	Coefficient of Variation:	0.17	0.18	0.34	0.97	0.85		
	Mann-Kendall Statistic (S):	1	1	-2	-16	9		
	Confidence Factor:	50.0%	50.0%	62.5%	96.9%	88.1%		
	Concentration Trend:	No Trend	No Trend	Stable	Decreasing	No Trend		



Notes:
1. At least four independent sampling events per well are required for calculating the trend. *Methodology is valid for 4 to 40 samples.*
2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C.J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.
4. Grey results indicate that the analyte was not detected above the reporting limit shown.

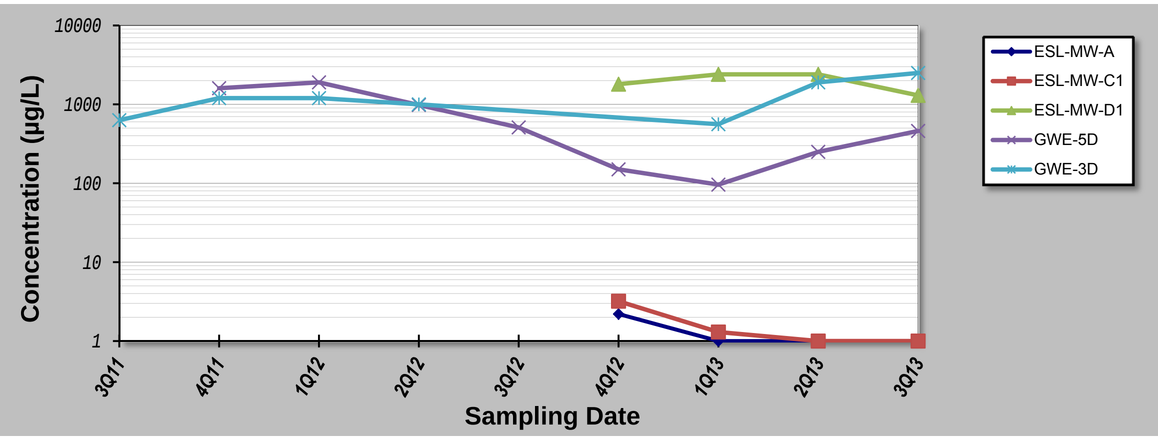
GSI Environmental Inc., www.gsi-net.com

Figure A3.8
Constituent Trend Analysis - The Mann-Kendall Test
Supplemental Monitoring Wells
Chlorobenzene

GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	November 2013	Job ID:	21562941
Facility Name:	W.G. Krummrich Plant, Sauget, IL	Constituent:	Chlorobenzene
Conducted By:	Nathan McNurlen - URS Corporation	Concentration Units:	µg/L

Sampling Point ID:		ESL-MW-A	ESL-MW-C1	ESL-MW-D1	GWE-5D	GWE-3D		
Sampling Event	Sampling Date	CHLOROBENZENE CONCENTRATION (µg/L)						
1	3Q11					630		
2	4Q11				1600	1200		
3	1Q12				1900	1200		
4	2Q12				980	1000		
5	3Q12				510			
6	4Q12	2.2	3.2	1800	150			
7	1Q13	1	1.3	2400	96	560		
8	2Q13	1	1	2400	250	1900		
9	3Q13	1	1	1300	460	2500		
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.46	0.65	0.27	0.92	0.54		
Mann-Kendall Statistic (S):		-3	-5	-1	-16	8		
Confidence Factor:		72.9%	89.6%	50.0%	96.9%	84.5%		
Concentration Trend:		Stable	Stable	Stable	Decreasing	No Trend		



Notes:

1. At least four independent sampling events per well are required for calculating the trend. *Methodology is valid for 4 to 40 samples.*
2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C.J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.
4. Grey results indicate that the analyte was not detected above the reporting limit shown.

GSI Environmental Inc., www.gsi-net.com